ILLUSTRATIONS

OF

TRADES.

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INTRODUCTION.

In that very amusing book, Boswell's Life of Johnson, we read :—"I have often been astonished with what exactness and perspicuity he [Dr. Johnson] will explain the process of any art. He, this morning, explained to us all the operations of coining, and at night all the operations of brewing, so very clearly, that Mr. McQueen said, when he heard the first, he thought he had been bred in the Mint; when he heard the second, that he had been bred a brewer." And in another part Boswell says :—"It gives one much satisfaction to find such a man bestowing his attention on the useful arts of life."

This anecdote of a great and good man suggests to us a few thoughts which may serve as an appropriate introduction to a book on Trades. In the first place it must be noticed that Dr. Johnson's biographer, and the persons with whom the Doctor was conversing, were struck with the great extent and accuracy of his information on subjects which he, as a literary man, could scarcely be expected to be acquainted with. And this knowledge is the more remarkable, because at the time referred to, the Useful Arts had not been illuminated and made intelligible by the lamp of Science. It is, however, in the nature of a deep thinker to be a keen observer, and to know thoroughly and well whatever he professes to talk about. And in this respect Dr. Johnson's example may serve as a useful lesson to ourselves. If we cannot attain to his great qualities, we can, at least, endeavour to imitate those habits of close observation and inquiry, which did not allow him to be satisfied with a thing until he thoroughly understood it.

We may observe in the second place, that the details of the Useful Arts, Trades, and Manufactures, may be naturally expected to possess a charm for deep thinkers and logical reasoners; since there is not a trade, however humble, that does not present to us a large amount of accumulated thought, the experience of many generations, if not of ages, as to the best methods of producing certain results, the best form of tool, the best mode of handling it, &c. In all these details, a high intelligence is visible *to* a high intelligence, mind claims affinity with mind, and delights in its exercise and application, although not on subjects peculiarly its own.

In the third place, a man of observation finds in the details of the Useful Arts large sources of prosperity to his country, and of peaceful and remunerative labour to his fellow-subjects. Dr. Johnson's definition of happiness was included in three words, "well directed employment;" and surely that employment is well directed, which supplies our ever-recurring wants, and makes men as dependent upon each other as they are upon the bounteous earth and sea, prepared by the Lord of all to fill "our hearts with food and gladness."

The mutual dependence of men upon each other in the production of the commonest article, is worth a little examination. Take so common an article as a needle. What a vast number of arrangements, what a wonderful complexity of interests are involved, before this little implement can be placed in the hands of the seamstress in its most efficient form; that is, not so hard as to break easily, not soft enough to bend, but perfectly smooth, sharp, with a well-formed eye that will not cut the thread, and opening into a groove which allows the thread to pass in readily. If we would write the history of a needle from the beginning, we must describe the magnificent forests of Sweden and Norway, where the miner is digging up a rich and pure iron ore, and the charcoal burner is felling the ancient trees and burning them into charcoal, so as to form a pure kind of fuel with which to smelt the ore, and so preserve the resulting metal from sulphur and other impurities which would deteriorate its quality. The metal, as it leaves the charcoal furnace, goes through sundry operations, and lastly appears in the form of bars of the best Swedish iron: these bars are stamped with peculiar marks, and are conveyed to the port of Oregrund (whence the iron is known in this country as *Oregrund iron*); there it is shipped and conveyed across the sea to the port of Hull, where merchants receive it and forward it to Sheffield for conversion into steel. At Sheffield it goes through a long process of cementation, ending in *blistered steel:* this is cast into ingots or tilted into bars, and passed on to the wire-drawer, who by a long and laborious process converts it into steel wire fit for the making of needles. Then, and not till then, does the needle-maker receive it in large thick coils: he cuts it up into lengths, equal to two needles each, straightens the wires, points the ends, forms the eyes, separates each length into two, rounds the heads, hardens and tempers the rough needles, submits them to a long and laborious course of polishing with oils and various polishing powders, drills the eyes, rubs up the points, sorts, examines, arranges and packs;

and finally sends them to the wholesale dealer, who distributes them to the shops and to the remotest corners of the habitable globe.

In this long detail what varied interests are brought into play! Men speaking another language, and with habits differing from our own, earn their daily bread in consequence of the demand for needles. Then what an amount of shipping is concerned, what a number of sailors, to say nothing of the ship-builders, the rope-makers, and the various subsidiary trades, any more than of the shops or fairs or markets where those poor Swedish workmen buy their necessaries of life, and let us hope some luxuries too; then again what an array of merchants and their clerks, porters and servants, what traffic on the railway, what numerous artisans engaged at Sheffield, and lastly what factories at Redditch, Feckenham, Bexley, and some other bright-looking Worcestershire villages with their neat cottages, all owing their prosperity to needles! But the history does not end here, for we must not only glance at the thousands of retail dealers, and the commerce of this little article, but we must also refer to circumstances calculated to touch our sympathy. There is something affecting in the thought that in the bazaars at Constantinople, Turkish women carry off packets of needles made in a Worcestershire village, which serve as the means whereby they earn their daily bread by embroidery work; while this in its turn is, perhaps, sent to England, to adorn the persons of our fair daughters.

The following work is intended as a companion to the "Illustrations of Useful Arts and Manufactures." The broad distinction between a manufacture and a trade is, that the one performs its work by means of self-acting machines, the other by means of tools in the hands of a skilled workman. This definition, however, must not be insisted on too rigorously, for as the word manufacture literally means "made by hand" and practically something else, so many a trade which was formerly practised by single workmen has now become a manufacture, in which all, or most of its branches, are carried on in one huge building, by hundreds of workpeople, often with the assistance of new or recently introduced machines. Of this, the bookbinder may be cited as an example. Bookbinding is strictly a trade in which there are many branches, all of which are exercised by skilled workpeople by the aid of a few simple tools. At the present day, however, a large London bookbinder's establishment resembles rather one of the great factories of Birmingham or Manchester than a tradesman's workshop; and a large amount of work, which was formerly done by hand, is now done partly by hand and partly by machinery, as in the *blind-tooling* and *gold-tooling* of books in which *block-presses* have been introduced.

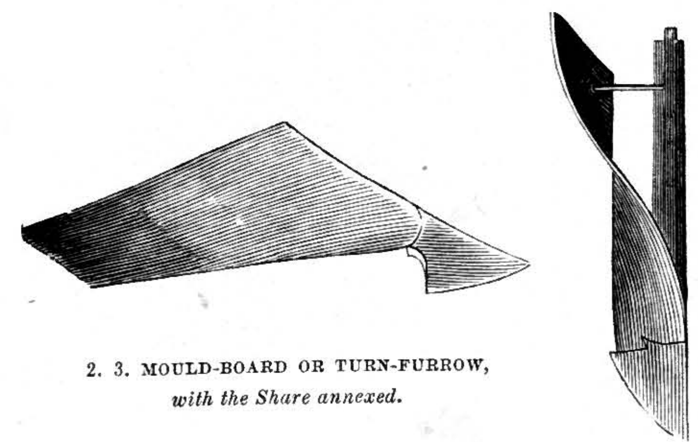
The Trades selected in these Illustrations refer to the supply of Food, of Shelter, of Clothing, of Furniture, of Locomotion, and of Education. This is the author's arrangement of the wood-engravings placed at his disposal. These were originally made for a kind of Pictorial Vocabulary for the use of the Deaf and Dumb, in which the trades were arranged in alphabetical order. As the artists who made the drawings do not appear to have had much technological knowledge, they have not made their selections with judgment, but have often omitted a tool or machine peculiar to a trade, and frequently repeated the saws, gimlets, and planes which are common to most trades. The writer has endeavoured to supply these defects by introducing in many places new engravings; but the result is by no means so satisfactory as if he had had the supervision of the artists in the first place, instead of having to deal with their crude results. As it is, however, the reader will find a large amount of information respecting the commonest trades, obtainable at a very cheap rate, in consequence of the great bulk of the wood-engravings, which have already served and are serving another purpose, being placed at the disposal of the Society for this work. The writer does not profess to give a complete book of trades, for he holds it to be useless to describe a trade, when he has not the means of sufficiently describing the object to be attained by that trade. For example, the Deaf and Dumb Vocabulary contains the tools used by the Watchmaker but not the working parts of the watch itself, which, with the clock, would require copious illustration. The writer has therefore preferred to omit such trades as could not be fully illustrated. Taking this work, however, in conjunction with the "Illustrations of Manufactures," the reader will find a large amount of information, collected both by the writer and the artist, on subjects in which we are all more or less personally interested.

The First Edition of this work appeared in 1860. In revising it for a Second Edition, the author has introduced many corrections, and some fresh details required by the progress of invention; such, for example, as a description of the Sewing-machine. In order not to disturb the numbering of the engravings, which are stereotyped, he has placed the Sewing-machine in a supplementary chapter at the end, and, for the same reason, some new engravings are introduced into the text.

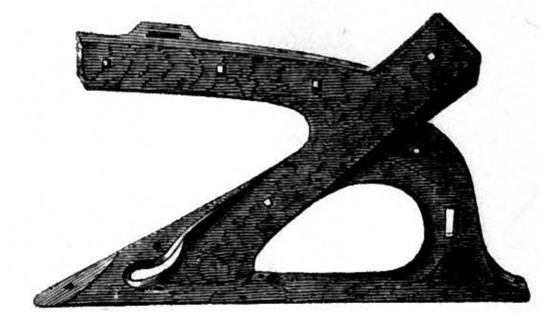
King's College, London.
1867.

THE FARMER.

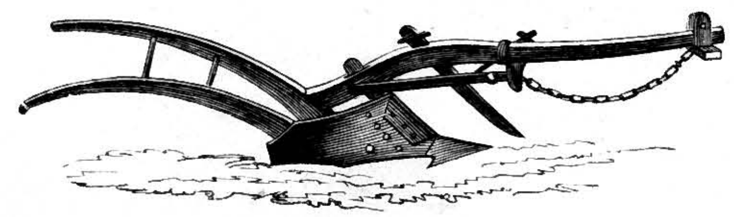
1. PLOUGHING.



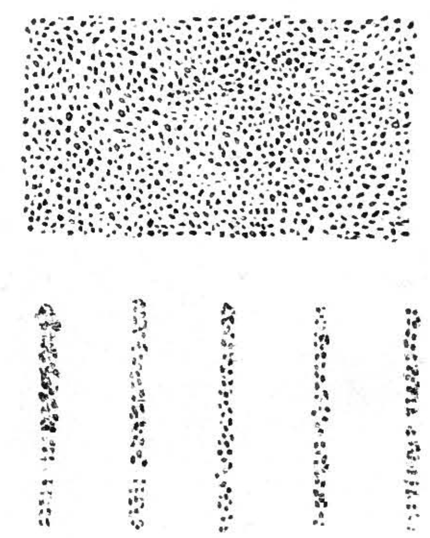
2. 3. MOULD-BOARD OR TURN-FURROW, *with the Share annexed.*



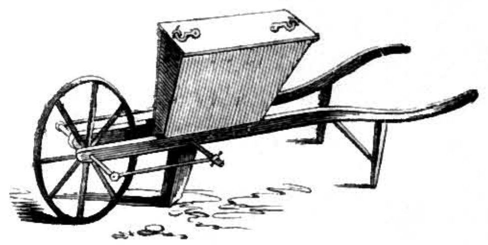
4. THE PLOUGH-FRAME.



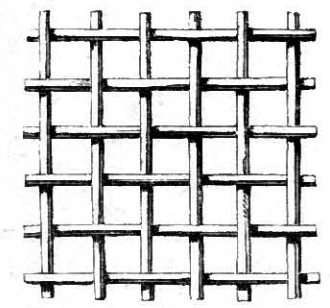
5. SMALL'S CHAIN PLOUGH.



6. 7. SOWING BROADCAST AND BY DRILL.

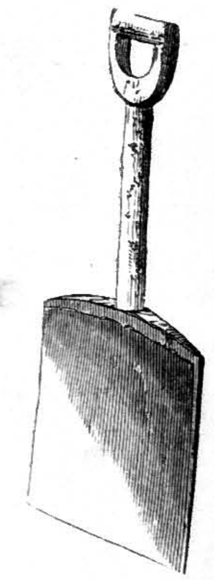


8. BEAN-DRILL.

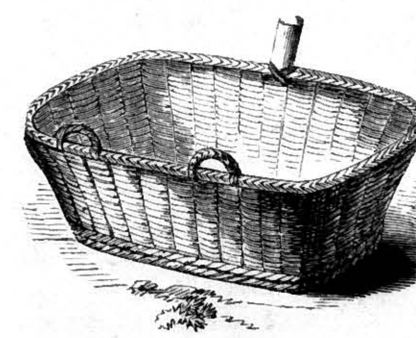


9. REAL SIZE OF MESHES IN WHEAT RIDDLE.

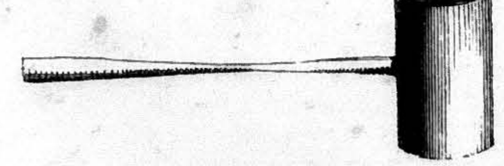
10. SOWING.



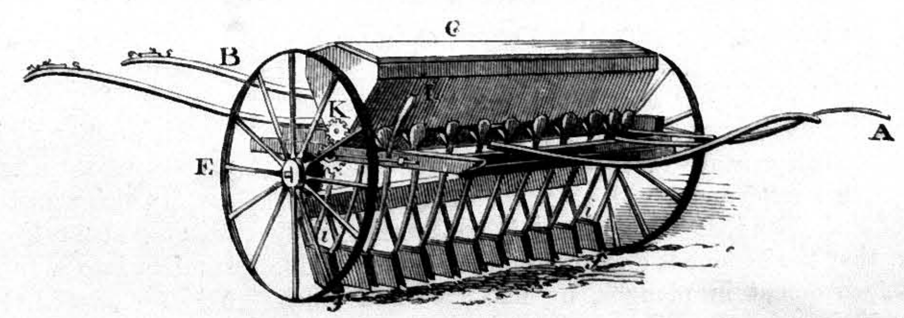
11. BARN-SHOVEL.



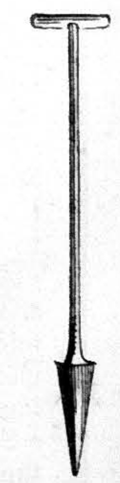
12. SEED-BASKET.



13. THE SHEPHERD'S MALLET.



14. DRILL-MACHINE.



15. DIBBLE.

I.—THE FARMER.

Agriculture cannot, strictly speaking, be called a trade, nor can it be rightly classed among manufactures, yet the farmer may be considered as the representative of a number of trades, by the exercise of which his labourers and servants earn their own living; while, at the same time, he holds that kind of relationship to these labourers which the manufacturer does to his workpeople, and lives upon the fruit of their toil in a similar way.

Taking the farmer, then, in the light of a representative of numerous trades, we proceed to notice the various operations and handicrafts carried on throughout the year in connexion with that diligent cultivation of the soil, that skilful gathering in and housing of produce, and that careful attention to live stock, which form the business, and contribute to the success of the agriculturist.

There is no time of the year at which the farmer can afford to be idle. Even "between hay-making and harvest," which is sometimes accounted his holiday time, or in "the dead of the year," when farming operations are checked by severe weather, there yet remains so much to be done, and his personal supervision is so constantly required, that he finds it difficult to get away from business on any errand of relaxation or pleasure.

Ploughing.—At all seasons of the year, but more especially in the spring and autumn, the ploughing of the land is a great and important work, and on its thorough and effective performance much of the success of the crops will depend. The best tools, the best workmen, and the farmer's eye, are all needed to insure a satisfactory result. The plough was originally a very simple implement: a stout limb of a tree, with a branch projecting from it, formed the rude means of turning up a light soil. The oxen were harnessed to the larger branch, while the smaller was shortened and pointed to serve as a ploughshare. Handles were afterwards added, and the ploughshare was shod with iron, in which form this peaceful implement was occasionally converted into a weapon of warfare; thus, "Beat your plowshares into swords," is a command given in the prophecy of Joel; happily counterbalanced by another prophecy of universal peace, when the nations of the earth shall "beat their swords into plowshares," and shall not learn war any more (Isa. ii. 4). The labour of the plough was comparatively light in the early period of the art (said to have originated in Egypt), for it was natural that when people were few and widely scattered, the spots easiest of tillage should be selected for cultivation; but as nations increased, and civilization extended, the less favourable lands were also brought into cultivation, and the implements were required to be better and more strongly constructed. At the present time, ploughs vary greatly in different parts of the earth, and betoken, to a great extent, the condition of the people in agricultural matters. In Bengal, a crooked piece of wood, sharpened at one end and shod with iron, is still used: to this two bullocks are attached, and the man or boy who guides the plough pulls the animals this way or that by the tail. In some parts of Poland the plough is a wretched implement, constructed by the peasant himself, and scarcely doing more than scratch the surface of the land. The ploughs of Spain and of European Turkey are also rude and simple in construction. Our own plough was in early times as rude as theirs, and acted more as a clumsy rake for stirring the surface, than as a plough for turning over the soil. Yet our early agriculturists were wise enough to see that one plough would not suit all descriptions of soil, and as early as 1532 there were "divers sorts," according as the soil was light or heavy. But it was not until the middle of the eighteenth century that any very decided improvement was made in this implement. Much as the plough has been improved and modified since that time, yet it is to James Small, a Scottish farmer, that the honour is due of producing, about 1763, the first great improvement in ploughs, by making them much lighter and easier of draught than they had previously been. The plough known by his name (fig. 5) is still in general use, and the essential parts of that, or of any other plough, are as follows. The *plough-frame* (fig. 4): this was formerly constructed of wood, but is now generally made of cast-iron, and to it the other parts of the plough are attached. Its lower part is called the *sole*, and to the front part is attached the *share*, a keen blade of iron, widening from the point, and cutting horizontally the long slices of earth which are immediately after to be turned over so as to be exposed to the action of the air. The share is shown in figs. 2, 3, attached to the *mould-board*, a very important part of the plough, varying in shape according to the nature of the soil in which it is intended to be used, and made (notwithstanding its name) of cast-iron. Its use is to push aside and turn over the slice of earth just cut by the share, so as to leave a regular furrow. When the share and the mould-board are fastened to the frame, what is called the *plough-body* is complete; and when to this is attached at the fore part the *beam*, and at the hind part the *handles* or *stilts*, the plough is fit for use, and has the appearance already referred to in fig. 5. The beam is about 3 feet long, and generally of wood: it has affixed to it in an upright position, a sharp cutting instrument called the *coulter*, the point of which nearly meets that of the share, and assists it in making a clean cut. At the extremity of the beam is the *plough-head*, a contrivance for regulating the depth of the plough and the line of draught. The stilts or handles extend backwards in the opposite direction from the beam, and are about 5½ feet long. They are wide enough apart for the ploughman to walk in the furrow as he raises, depresses, or turns the plough by holding these handles, and guiding them with the skill which experience teaches. The kind of plough represented in fig. 1 is called a *swing-plough;* but some ploughs are furnished with one or two wheels, and are called *wheel-ploughs.* Swing-ploughs are considered lightest of draught, but they require an experienced and attentive ploughman: wheel-ploughs work with greater steadiness, and require less skill in the guide. In the present rapid march of improvement in agricultural matters, there is reason to believe that before many years shall have elapsed, this ancient occupation will, in some parts of the country, be taken out of the hands of our slow but sure labourers, and will be accomplished by *steam-ploughs*, which will require a different mode of management.

Wheat-sowing.—Ploughing and harrowing are the preparatory steps to that great business of autumn and early winter, *wheat-sowing*. In our illustration (fig. 10), that further harrowing which follows sowing is represented: it is a raking of the soil by means of a square frame of wood, furnished with a number of teeth, and drawn by horses, and it comes immediately after the sowing, because it would not do to leave the seed uncovered. Usually the sower has free scope for his work in a large open field, thoroughly prepared for the seed, and where the trees and hedgerows do not form an important feature. On the colder soils he commences his task in September or October, that the plants may obtain strength before winter sets in: on warm and rich soils he defers his task until November, lest the plants, by growing too rapidly, become what is called *winter-proud*, and thus yield in the following autumn a light crop.

The choice of seed is an important consideration, and can only be acquired by experience of the nature and requirements of the soil. And when the best seed has been selected, full, plump, sound, healthy, and free from the seeds of weeds, the preparatory process of *steeping* is necessary to save it from a disease called *smut*, which sometimes renders a crop almost worthless. A basket holding about half a bushel is filled with corn, and lowered by handles into a tub of strong brine, or of chamber-ley, where it is held for two or three seconds, sometimes for several minutes, then lifted up and placed upon two sticks over an empty tub to drain,

until another basketful is ready. The first basket is then poured out on the clean floor of the barn, and sprinkled with slaked caustic lime, from a wheat-riddle; another basket of wheat is served in the same manner, and so on: the whole heap of pickled and limed wheat is then repeatedly turned over by means of the barn-shovel (fig. 11), put into clean sacks, and carted at once to the field, only a sufficient quantity for one day's sowing being pickled at one time. If it is to be sown by hand or *broad-cast*, the sower fills a basket (fig. 12), slung across his shoulders, or it may be a box called the *seed lip*, of a similar shape, or it may be merely a large cloth, gathered into a kind of pocket or bag, and called the *sowing-sheet*. Keeping the hand low, taking up the seed firmly, and making short steps in advance, he casts forth the seed at every step, making it fly in a curve from right to left, and scattering it with an evenness and regularity which appear quite wonderful to inexperienced eyes. If the seed is to be sown by drill, it is placed in the seed-box, *C*, of a machine represented in fig. 14, within which seed-box, at its lower part, is a spindle or axle *K*, turned by the axle of the wheels. A series of grooved or fluted cylinders fixed to this axle, and revolving among the seeds, collect the wheat, and pass it in small regulated quantities through apertures in the bottom of the box, and into tubes or funnels, *i, i*, by which it is conveyed directly to the ground. Immediately before the lower part of each funnel, is a sharp hollow coulter of iron *f, f*, which forms the drill in each case just in time to receive the seed. By elevating the handles *A*, these tubes or funnels are lifted up when obstacles come in the way. This machine runs on large light wheels *E*, and is attached to the one or two horses which draw it by the shafts *B*. The appearance of the two modes of sowing (broad-cast and by drill) is shown in figs. 6, 7. On certain light soils throughout England, a method of sowing called *dibbling* is practised. A light roller is passed over the prepared soil, after which a man, walking backwards with an iron dibble (fig. 15) in each hand, makes two rows of holes, and children following on his steps drop a few grains of corn into each hole, which is afterwards filled up by the passing of a roller or a bush-harrow over the soil. This mode of sowing is employed on light and sandy soils, and answers well in such situations.

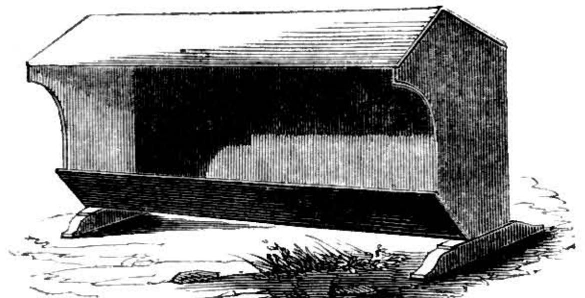
Sowing, Weeding, Feeding Sheep, &c.—We have spoken of wheat-sowing as an autumn and early winter employment, but it is also carried on in the spring, when barley and oats, turnip-seed, mangold wurzel, beans, peas, &c., are also committed to the earth. Bean-sowing is in some places performed by dibbling, as above described, but oftener by a small machine called the *bean-drill* (fig. 8). A bean-field in blossom is one of the prettiest sights of the country, and the plants are often as nicely kept as a garden crop, being carefully weeded with the *weed-hook* (fig. 37), in their early growth, and further protected afterwards by a double mould-board plough being driven between the ranks to throw the earth up in high ridges (fig. 26). Meanwhile numerous occupations are pressing on the farmer in this busy season of spring. Sheep-washing and sheep-shearing demand the care of those who cultivate flocks. In feeding sheep, a useful machine called a *turnip slicer* (fig. 20) is often carried to the field, and portions of the turnips in succession are pulled up, and cut in pieces for the sheep, who are apt to be wasteful when they help themselves. *Hay-racks* (fig. 25) are also generally provided for them, and these the shepherd fills afresh every day. These racks have a solid cover, which keeps the hay dry, and also affords some shelter to the sheep in wet weather, they being often found lying down on the side of the rack least exposed to the weather. In folding his sheep, the shepherd sometimes uses hurdles, sometimes nets: in the latter case, he drives in stakes at regular intervals by means of his *mallet* (fig. 13), and then attaches a netting of twine by means of a strong rope which passes through the top and bottom meshes, and which he secures to each stake by what is called the *shepherd's knot* (fig. 27). The food of the sheep consists, not only of hay and sliced turnips, but in time of need, of oil-cake, brewers' grains, potatoes, mangold wurzel, &c. For all such food, the *feeding-box* (fig. 18) is useful.

Milking, Butter-making, Cheese-making.—Dairy-work is another important spring employment: the early dawn, and the early evening, find the farmer's boy engaged in driving home the cows (fig. 22), and soon the well-known operation of *milking* (fig. 17) is carried on. Regularity, gentleness, and cleanliness are the requisite qualities in a milker; the same person, if possible, taking the same cows day by day, and milking them in the same order, while they are eating their fodder. The milk is carried to the dairy, a cool stone-paved room facing the north, and generally shaded by trees, and is there exposed in large shallow pans to a draught of air for twelve hours, in which time all the best of the cream has risen to the surface. This cream is skimmed off, and collected in a large jar for making butter. In dairies of the usual size, the cream is churned every two days. The common *upright churn* (fig. 24) is a wooden cask diminishing in size towards the top, and having a moveable round lid, with a hole in the centre. Through this hole a stick passes, having at its lower end a round flat board with holes in it. By moving this stick up and down, slowly at first, and more rapidly afterwards, the cream in the churn gradually gives up its butter, which forms into small lumps. It is necessary to attend to the temperature of the churn, or the butter will not "come good," or without some hours' churning. It is said that butter will always come in half-an-hour, if the temperature of the cream be about 55° of Fahrenheit's thermometer. When the butter is formed, there is a residue in the churn known as *butter-milk:* this is given to the pigs. The lumps of butter are collected and placed in a shallow tub, where they are worked into a mass with the hands or with a wooden beater, weighed up into pounds, and printed or rolled. The agitation of the cream which is necessary to produce butter, is often performed in what is called the *barrel-churn* (fig. 30), which is a barrel turning on an axle by means of a common winch, and moved by the hand, by horse-power, or even by steam. But we have only accounted for the cream of the dairy, and it is now time to refer to the important uses of the milk. Milk, if left to become sour, separates into two parts, *curd* and *whey*. Curd is the material for making cheese, but the product is not very agreeable if obtained from sour milk; therefore dairy-men have a method of curdling the milk without allowing it to become sour. But this is not done until a certain colour has been given to the milk, according to the sort of cheese to be made. The order of the work may be briefly stated thus: the milk in the cheese-tub is coloured by means of *annotta*, a hard reddish-yellow substance, obtained from the rind of the seeds of a South American plant (fig. 16). A little of this dye, which is tasteless and harmless, is dissolved in a small bowl of milk, making a deep coloured solution, and this is gradually mixed with the whole mass, which is then turned by means of *rennet* (a preparation from the inner membrane of the fourth stomach of a calf) into curd. When the curd has fully formed, the dairy-maid breaks it up into fragments no larger than a hazel nut. This she does either with her hand and a small wooden dish, or with an instrument called a *curd-cutter* (fig. 23); she then presses in and piles up this curd in a small vat, the size and shape of the cheese to be made, on which she has previously spread a cheese-cloth, the ends of which she now turns over the top of the curd, and places the whole in a *cheese-press* (fig. 31), where it is subjected to considerable pressure, and where its superfluous whey runs off through holes made for the purpose in the bottom of the cheese-vat. In two days, during which the new cheese is taken out three or four times, wiped, turned, and replaced in the press, it is sufficiently solid to be placed in the salting tub, where it remains covered with brine for several days, and is afterwards taken out, and rubbed with salt daily for another week or ten days. It is then taken to the cheese-room, where repeated wipings, turnings, and airings keep it from premature decay. The quality of cheese varies with the quality of the milk. This is sometimes ascertained by an instrument called the *lactometer* (fig. 35), which consists of graduated tubes, into which the milk of different cows is poured; and by the amount of cream which settles at the top of each tube, the richness of the respective milks is ascertained.

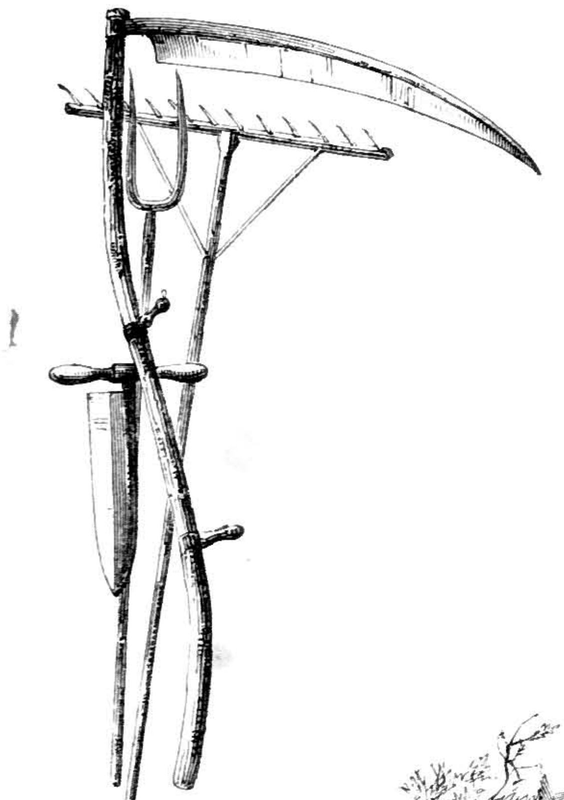
Hay-making.—Spring advances, and soon these blooming pastures must yield their fragrant and nourishing grasses to the *mower's*

16. ANNOTTA PLANT. (*Bixa Orellana.*)

17. MILKING.

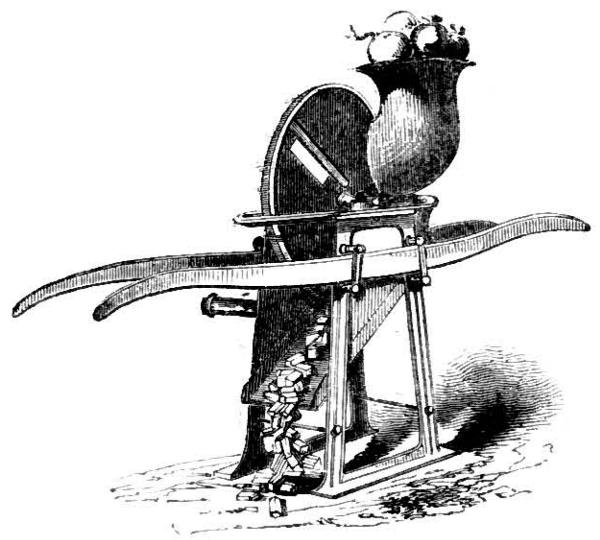


18. FEEDING-BOX.

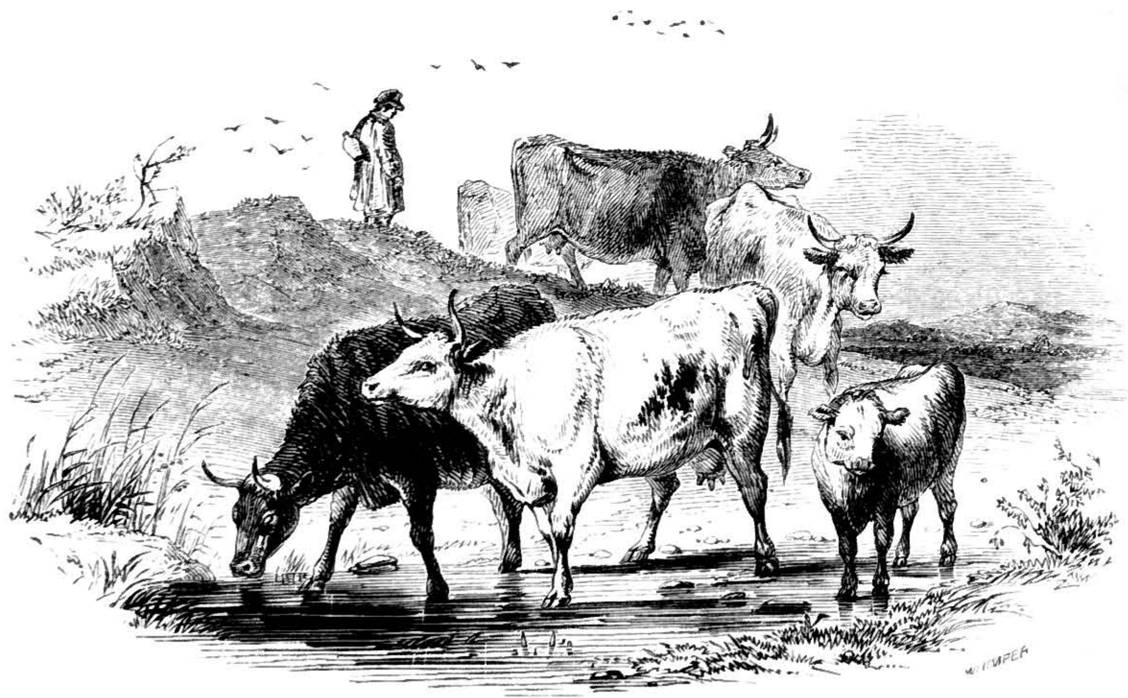


21. HAY-MAKING IMPLEMENTS.

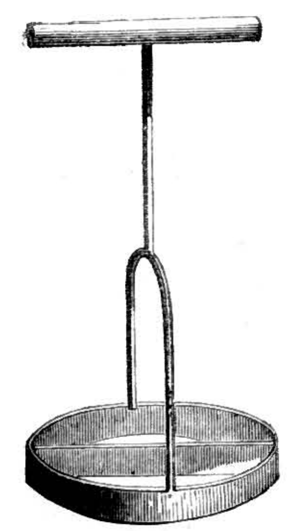
19. HOEING TURNIPS.



20. TURNIP-SLICER.

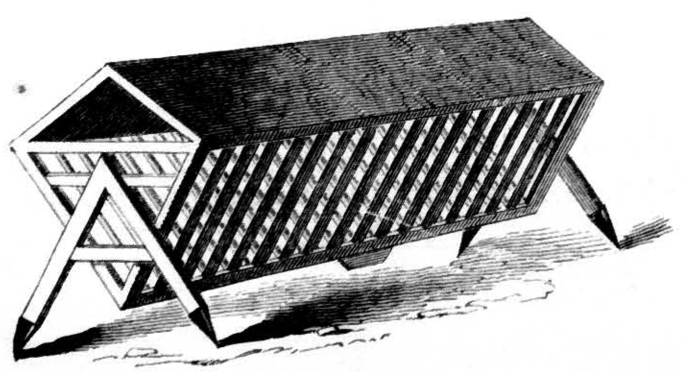


22. FETCHING HOME THE COWS.

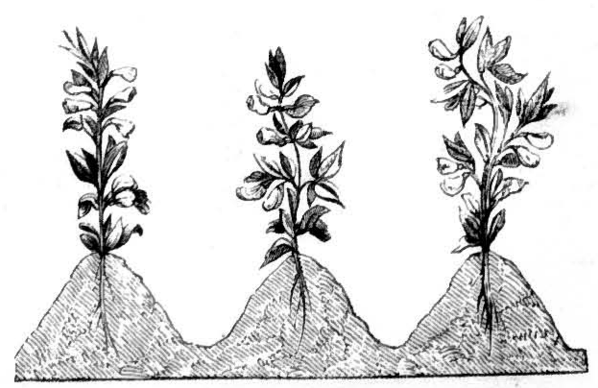


23. THE CURD-CUTTER.

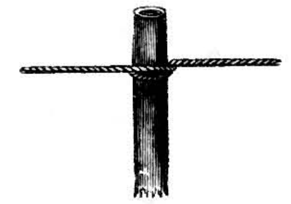
24. UPRIGHT CHURN.



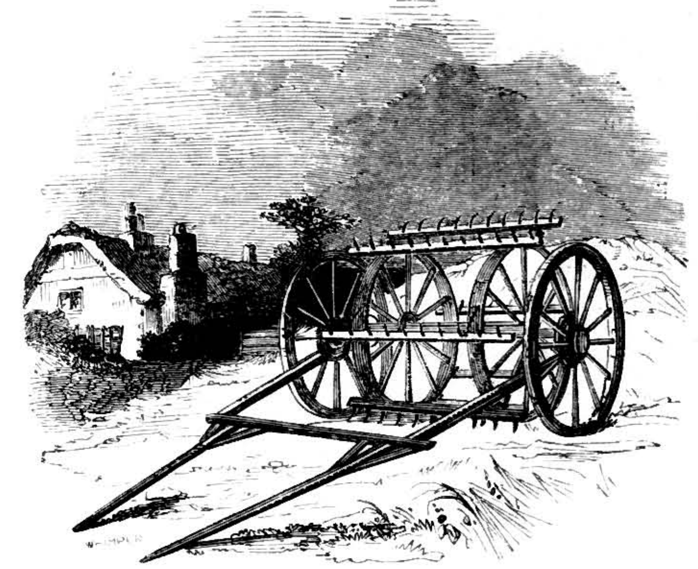
25. HAY-RACK.



26. BEANS CULTIVATED ON RIDGES.

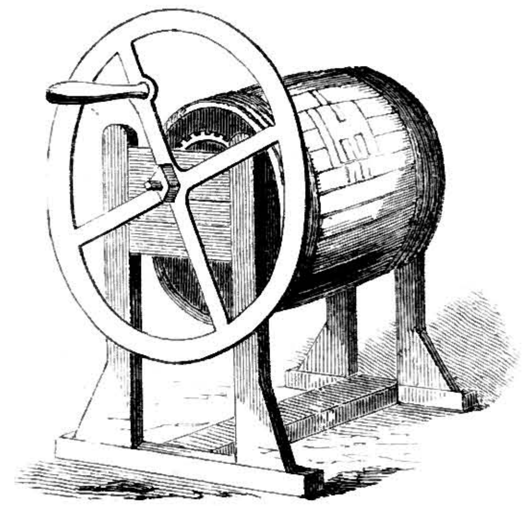


27. THE SHEPHERD'S KNOT.

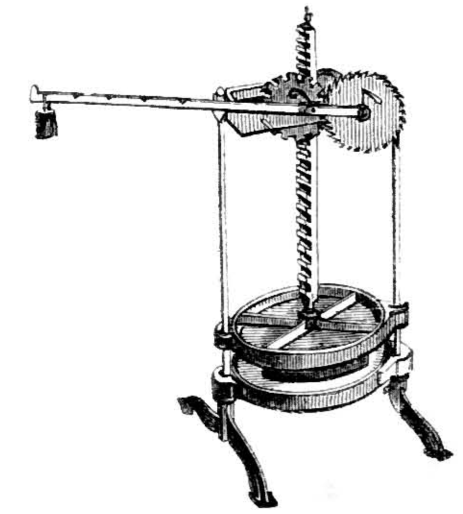


28. HAY-TEDDING MACHINE.

29. WINDLE, OR TURNER.



30. BARREL-CHURN.

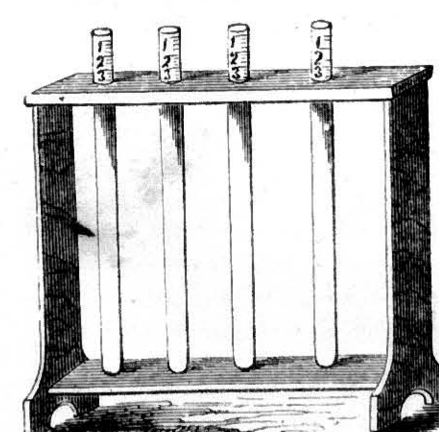


31. IMPROVED CHEESE-PRESS.

32. MOWING.

33. LOADING HAY.

34. WHETTING THE SCYTHE.



35. THE LACTOMETER.

36. THE RICK-CLOTH.

37. THE WEED-HOOK.

scythe (fig. 34); for no sooner have the fields and hedgerows attained their utmost beauty, than hay-making begins, and hundreds of wild flowers fall at every sweep of the *mower's* arm (fig. 32). The spreading and tossing of the grass, until it has dried into hay, is usually the pleasant task of men and women with long rakes, who finally gather it into haycocks, and help to *load* the wagon (fig. 33), which bears it to the rick-yard; but in the neighbourhood of large towns, the process is hastened by the use of the *hay-tedding machine* (fig. 28), which is drawn by one horse, and which catches up and tosses about the new hay in a constant whirl. The variable nature of our climate at the hay-making seasons, makes this a very precarious crop; and when put together in a damp condition, the hay sometimes ferments to such a degree as to take fire. Care is therefore necessary not only to collect the hay in a dry state, but to keep the rick dry while making. This is now facilitated by the *rick-cloth* (fig. 36), a useful article, suspended by means of poles and cords over the rick, and forming a roof to it, while it is being made. Haymakers find many a use for a rope of hay twisted on itself, and called a *hay-band*. This is made by means of a little instrument called a *windle* or *twiner* (fig. 29); the hay is damped, and is readily twined into a tolerably strong rope, which serves to tie up the hay in trusses, &c. The *mower's scythe*, the *prong*, and the *rake* form the group of hay-making implements in fig. 21; while the *hay-knife*, shown in the same group, is used for cutting the hay of the rick into trusses.

Wheat-harvest.—All through the hay-making season, the farmer's watchful eye has been frequently turned on another crop, the most important of the whole year, now approaching perfection. The term *harvest* applies to the gathering in of all the crops, whether of wheat, barley, oats, or of peas, beans, &c. But we can only now speak of the *wheat-harvest*, the grand object of attention to the farmer, during which he postpones as far as possible all other business and pleasure, and devotes himself, heart and hand, to his work. The number of insect enemies which beset the wheat-crop is so great, that it seems wonderful how any crop can reach perfection. Notwithstanding all precautions of steeping, liming, &c., the grain is no sooner committed to the earth and beginning to vegetate, than it is sometimes attacked by a caterpillar (that of the *Wheat Dart Moth*), which feeds on the young root. In the spring another enemy appears in the *Wheat Stem Fly* (fig. 41), which lays its eggs in the very core of the young plant, entirely destroying the primary shoot. Such is the vigour and activity of the root, however, that a dozen new stems and ears are sometimes sent up to repair the mischief and thus the apparent enemy becomes a friend. Later in the season, the *Wheat Midge* (fig. 40) deposits eggs in the blossom, the young larvæ feeding on the pollen, and causing the grain to shrivel and decay. These larvæ are in their turn attacked by a small black fly called an *ichneumon*, which inserts her eggs beneath their skin, and these, when hatched, feed on the caterpillars to their destruction. While these evils are going on above ground, the *Wire-worm* and the *Slug* are at work below. The wire-worm is the grub of an insect called (from a peculiar sound which it makes) the *click beetle*. The worm is long and tough, of a deep yellow, except the head, which is brown. Diligent hand-picking is of some use in checking this evil when it attacks turnips, fifty worms having been found in one turnip. In wheat-fields slices of potato fixed on skewers are sometimes buried and pulled up at intervals, and the worms removed. At other times the land is watered with a saline solution, or it is left fallow until the enemy is starved out. Another evil to the wheat-crop is called *ear-cockle*, *purples*, or *pepper-corn*. The grain becomes nearly black, and rounded like a pepper-corn. It is full of a cottony-looking substance, which under the microscope proves to be a multitude of writhing active creatures like snakes. This is one of the most serious of the many forms of *blight*, consisting of that vast development of microscopic insects, or of parasitic fungi, which forms so wonderful a field for inquiry and observation.

Reaping.—But supposing the crop to have arrived at healthy maturity, the glad preparations for harvest are made, and soon the fields present a lively scene, with reapers bending amidst the corn (fig. 46), and masters riding from place to place to superintend their labours. The ordinary implement for reaping is the *sickle*, a simple hook of iron, edged with steel, which does its work well and with little waste when it is in good hands. A good reaper crouches down on his right leg, and extending the left to steady himself, seizes small portions of corn with his left hand, and with his right draws the sickle across their stems, as near to and parallel with the ground as possible, pulling it towards him as he does so. Without changing his position, he makes a sort of creeping movement towards the left, and cuts another portion, laying the corn in handfuls within a band made of corn-stalks which is used to bind up the sheaf, a task performed by another person who follows the reaper. Corn is now frequently reaped with the scythe instead of the sickle, which is a more expeditious process, but gives more trouble in setting the wheat up in stacks. Where the scythe is adopted, strong and able workmen are required, the task being one of the hardest known in agriculture. The nature of his implement prevents the scythe-reaper from laying the corn evenly on the bands, therefore another labourer follows for that purpose; a third binds the sheaves, and a fourth clears the ground with a rake. When the bandster has made a sufficient number of sheaves, he sets them up in a stack or shock. He takes two sheaves, one in each hand, sets them a little way apart on the ground, and brings their heads together. He then sets up others, until a double row of sheaves, seven in length, is set up, each pair supporting itself and not leaning against the others, although close to them. Barley and oats are frequently *hooded*, that is, covered in by inverted sheaves, but wheat is seldom protected in this manner. Small sheaves are preferred to large ones; they are sooner dried, and less liable to damage. If the wheat be secured in really good condition, the grain will be plump, smooth, and of a bright colour.

Loading, Stacking, Threshing, Storing, &c.—When dry and fit for carrying, the sheaves are loaded and taken home to form stacks. These have a raised platform of wood or iron, on which the sheaves are cleverly built up with the grain inwards, and are secured at the top by a covering of thatch. Here they are safe, and form stacks, which as they multiply in the rick-yard afford goodly evidence of the abundance of the harvest and of the wealth of the farmer. In this state the ricks may remain for months or years, as it may suit the pleasure or convenience of the owner; but when the time comes for taking in the rick, and for threshing and selling, or stowing the grain, the proceedings are as follows:—The work of taking in a rick (fig. 39) occupies a few labourers, and a superintendent; the latter mounts the rick and cuts away the tyings of the straw ropes at the eaves, preparatory to removing with a small pitchfork the whole covering of the rick, and throwing it on the ground. The labourers spread out a layer of this straw on the ground on the side of the rick nearest the barn, and spread the barn-sheet upon it, drawing the latter close to the rick. This is a large piece of thin canvas about 12 feet square, and upon this the sheaves are thrown down, and thence conveyed in barrows to the barn, where they are piled up in rows to a considerable height with their butt ends outwards. In this way the whole rick is taken in, and the loose corn in the barn-sheet is also emptied on the barn-floor. If possible a dry day is selected for the work, and a stack thus housed may remain in the barn without injury until a wet day deprives the labourers of out-door employments, and makes it convenient to resort to the *flail*. This is a simple implement, but its use requires a great expenditure of time and labour, hence the farmer often resorts to machinery. The flail consists of two rods of ash of unequal length, connected by a loose swing joint of leather; the longer rod, called the *helve*, is held in the workman's hands, while the shorter rod, or *beater*, is applied to the threshing out of the corn. The skill of the work consists in making every part of the beater strike the floor with equal force, and have its full effect on the opened sheaves; hence the peculiar dull flat sound of the flail, which is heard hour after hour, with little variation, in some farm-yards. But more frequently a sound, louder and more shrill, announces that machinery is at work; and on looking into the rick-yard, the threshing-machine (fig. 45) is seen in full action with a

horse attached to each of the projecting beams, and a boy seated in the centre holding in his hand a long whip, with which he keeps up the speed of the poor animals condemned to this giddy round of labour. The action of the machine on the wheat will be understood by reference to fig. 49, which shows the working parts. At *A* are fluted iron rollers between which the unthreshed corn passes, straw, ears, and grain. Thence it is carried over a cylinder or drum *B*, containing four projections or beaters which revolve rapidly. It next reaches a second cylinder where it is acted upon by four rakes, and where the grain and chaff fall down into a winnowing-machine below, and the straw is carried on to another cylinder *D*, where it is again shaken by rakes before it is thrown out at the end of the machine. Sometimes there are brushes affixed to the last cylinder, in order to sweep back any corn or chaff which may have fallen into the cavity at *E*. Whether the corn be threshed by flail or machine, the next operation is *winnowing*. The *winnowing-machine* (fig. 50) is simple in its construction. Four or more boards are fixed at equal distances from each other on an axle, extending through the machine, and whirled round by a wheel acting on a pinion. A current of air is thus produced within the machine, and the corn which is put into a hopper at the top falls gradually through this current, and the chaff is blown out at the tail of the machine, while the heavy grain falls down and is collected beneath. The corn thus winnowed is next riddled, in order to separate earth, stones, &c. Sieves or riddles of different degrees of fineness are used (figs. 43, 44), but the meshes must always be rather coarse, to allow the grain to pass through; the usual size is shown in fig. 9. Corn is measured out by the *Imperial bushel* (fig. 48); this is 8 inches deep, and rather more than 18½ inches across, and contains 2,815 cubic inches. The grain is swept off on a level with the rim of the bushel by a flat piece of wood, called a *strike* (fig. 42). Three of these bushels make one *sack*; in moving the sacks of wheat from place to place the *sack-barrow* (fig. 38) is used. In former years, wheat was largely stored in granaries, as is still the custom in some parts of the Continent, though it has fallen into comparative disuse in this country.

Where this custom still prevails the proceedings are as follows:—The granary, which is generally in some high and dry situation, receives the corn by degrees. It occupies the floor in heaps, spaces being left between them, both for ventilation and for the convenience of the labourers, who at stated intervals turn and toss the grain with their barn-shovels. At first only about six inches in depth of corn is placed on the barn-floor, and this is completely turned at least twice a week. A month later, another six inches of corn is added, and the whole is turned once a week. After six months have elapsed, the heaps are raised to two feet in thickness, and are turned about once a fortnight, so the corn is gradually raised, and the turnings become fewer as the mass becomes less manageable; but however long the wheat may remain in the granary, it is improved by frequent turnings, and by passing through screens or large sieve-like frames. Granaries have more than one story (public granaries have seven, eight, or nine stories), and in some cases there are large square or circular holes in the floor, through which the corn is tossed from the upper to the lower room. Where corn is properly turned, screened, and ventilated, it can be kept in one climate as long as thirty years. In Switzerland, corn has been kept eighty years by the same means. In Russia, corn is preserved in subterranean granaries, wide below and narrow above, and the wheat is kiln-dried while in the sheaf, because the summers are too short to allow of its being properly dried in the field. Some plan of this kind has been recommended in Great Britain, where the autumn is sometimes so wet that the ripe corn is spoiled before it can be properly housed.

Every part of the wheat plant is useful; even the chaff or husk of the grain is in some places mixed with corn and given to cattle. Wheat-straw is used in the manufacture of hats and bonnets, of baskets, boxes, mattresses, bee-hives, &c.; it also forms the best kind of thatch. It forms also a considerable part of the provender of live stock, and for this purpose is cut into short lengths by a machine called a *chaff-cutter* (fig. 47), and the straw when thus mixed up is called *chaff*, it being divided into portions as small as the real chaff or husk of the grain.

Cider-making.—When the main business of the harvest is over, a time of comparative leisure gives opportunity for the ingatherings of the orchard and garden. In some parts of England, especially in the cider districts of Hereford and Devon, the gathering in of apples and the making of cider become a general employment, occupying a large number of hands; in other parts of the country, where the orchards are comparatively small, it is yet common to see the cider-press at work, or on its road from one village to another, as it is let out on hire to different persons in succession. Cider-orchards began to be planted in Herefordshire in the reign of Charles I., and the first cider made in England was esteemed as highly as foreign wine, and was expected to supersede its use. And in fact, at the present day, the best and sweetest cider forms the staple of many wines sold as foreign.

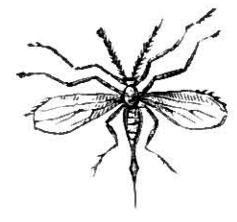
If we trace the cultivation of the apple from the commencement, we find the first step to be, the preparation of a soil of good quality as a nursery ground, and the planting therein of a number of young seedlings of the crab, six feet apart. The following year they will be fit for *grafting*, that curious and interesting art by which the shoot of a tree bearing large and delicious fruit is incorporated with the hardier stock of an inferior tree of the same species, and becomes a flourishing tree, bearing, not the sour fruit of the stock, but the rich fruit of the scion. In its wild state, the apple is nothing more than the sour crab of our hedges; in its domesticated state it seems capable of almost endless improvement.

Grafting.—There are several different kinds of grafting, named according to the form of the graft and the mode of insertion:—thus, in *saddle-grafting* (fig. 51), the stock is cut in the form of a wedge, and the graft is shaped so as to fit over it like a saddle; in *whip* or *tongue grafting* (fig. 52), the stock is cut through in a slanting manner, and the scion is cut into a long tongue, which fits the stock and is its exact counterpart; in *crown-grafting* (fig. 53) (only performed on large stems or limbs with thick bark), the limb is sawn through horizontally, a piece of flat wood or ivory is then slipped between the bark and wood so as to make a small cleft or opening in the crown of the stock, and into this the graft is inserted. In *cleft-grafting* (fig. 54), the stock is also sawn through horizontally, and cleft deeply, the cleft being kept open with a chisel until the graft is inserted, when it closes firmly on it.

Whatever may be the form of the graft, it is bound and secured with strips of matting, and further protected with grafting-clay, or some other composition, pressed round the stem so as to exclude the air, until the union of the scion and the stock be complete. Grafting is performed at two years old; but it will be five or six years longer before the trees come to their full bearing. The young trees are transplanted from the nursery to the orchard before their branches begin to interfere with one another. The month of October or November is the best time for this work, when, if carefully removed, the trees will send out a few rootlets before winter, and make a vigorous growth in the spring. Most of their side branches are taken off previous to transplanting, but the roots are carefully preserved and placed in a hole deeper than that from which they were taken, and wide enough to allow of their being spread out in a natural manner, before the soil and turf are covered in upon them. Each transplanted tree requires for the first year a stake and a few bushes to protect it. A straight stem six feet high, and three or four healthy shoots to form a head, are the requisites for one of these orchard trees or *standards*. A smaller tree dwarfed by judicious pruning is grown in gardens and called a *dwarf*. This is more generally adopted in the present day than the old form of training apple-trees on a frame, when they were called *espaliers*. But there is many an old-fashioned garden in which these espaliers still form the tempting fruit-wall which divides the flower-beds from the vegetables. Young trees of too luxuriant growth, whether espaliers or standards, must be checked by judicious pruning, but this process is best performed in the youth of the tree; for it is apt, unless caution be observed, to do serious injury to old trees.

38. SACK BARROW.

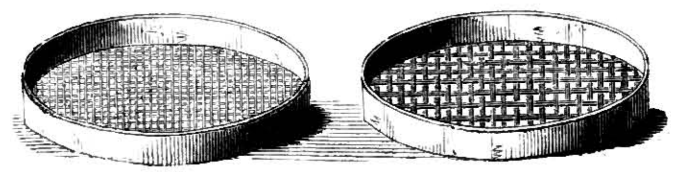
39. THE FLAIL.



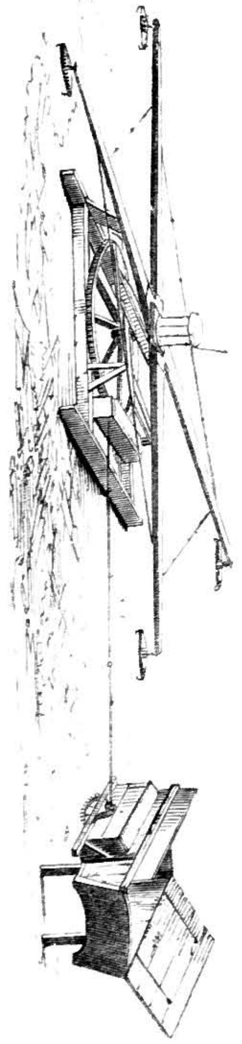
40. WHEAT-MIDGE. *Magnified.*

41. WHEAT-STEM-FLY. *Magnified.*

42. THE STRIKE.



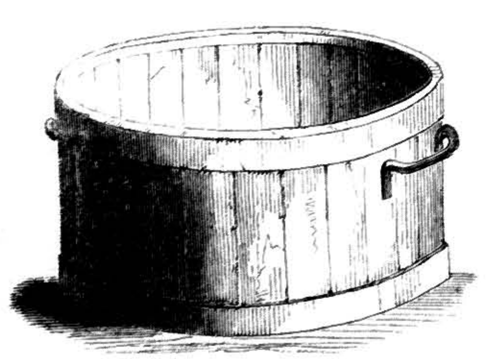
43, 44. CORN RIDDLES.



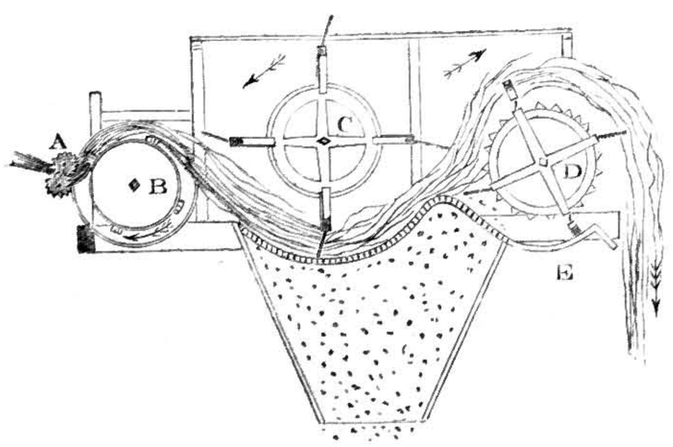
45. THRESHING-MACHINE.

46. REAPING.

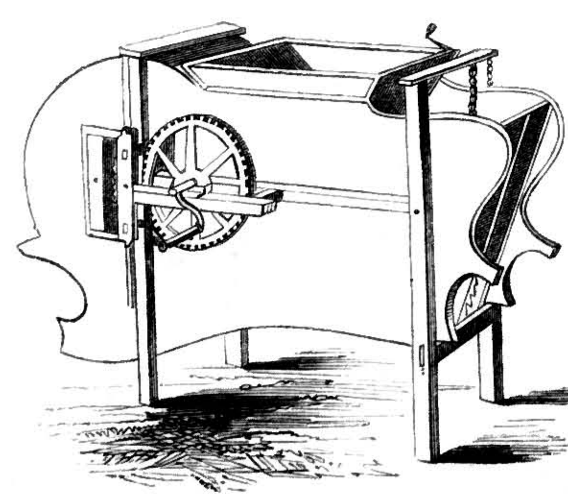
47. CHAFF-CUTTING.



48. IMPERIAL BUSHEL.

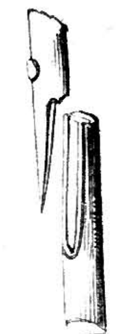


49. WORKING PARTS OF THRESHING-MACHINES.

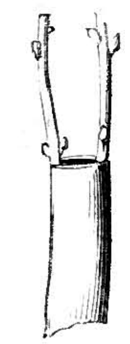


50. WINNOWING-MACHINE.

51. SADDLE GRAFTING.



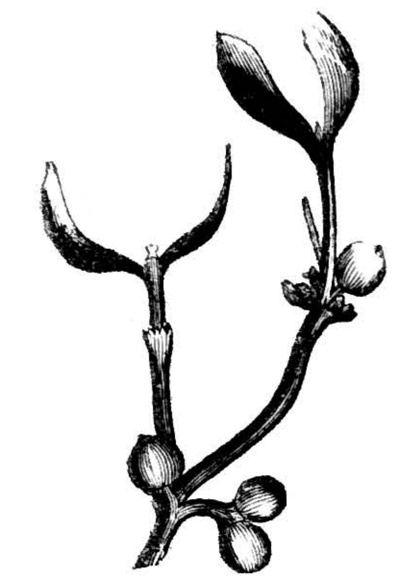
52. TONGUE GRAFTING.



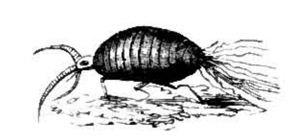
53. CROWN GRAFTING.

54. CLEFT GRAFTING.

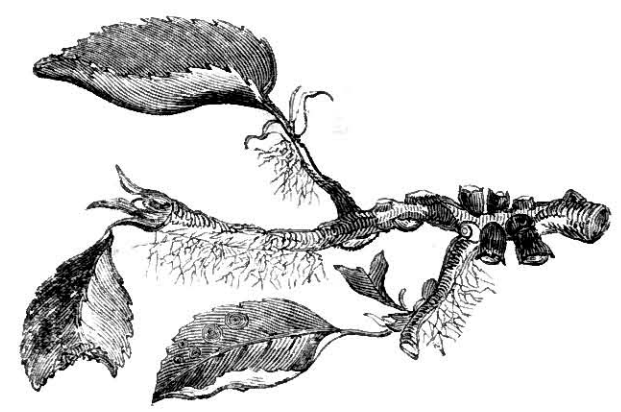
55.



56. COMMON MISLETOE.

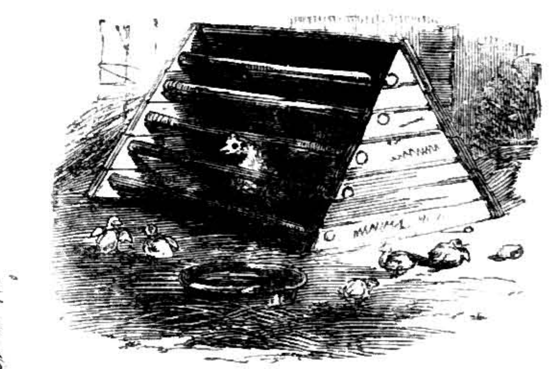


57. AMERICAN BLIGHT. (*Magnified.*)

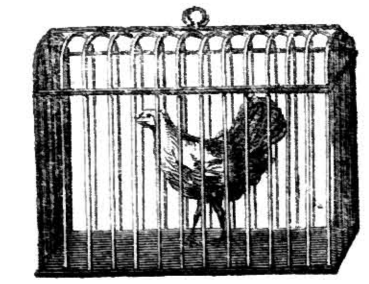


58. BLIGHTED BRANCH.

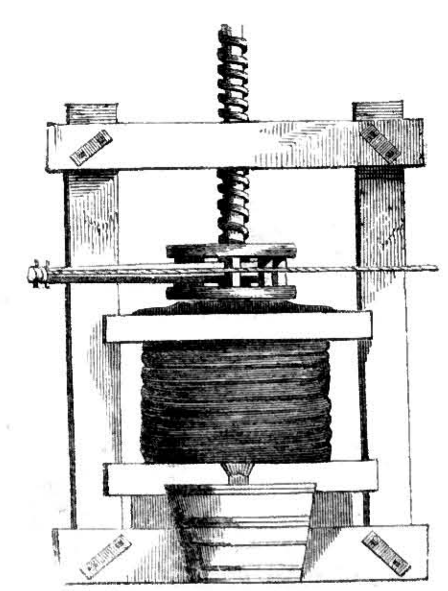
59. GATHERING APPLES.



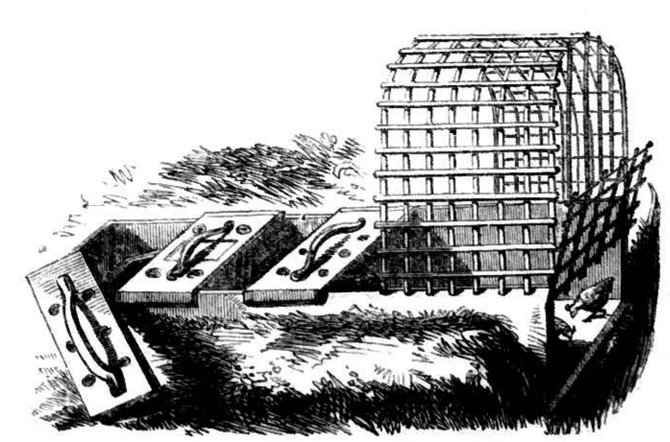
60. HEN COOP.



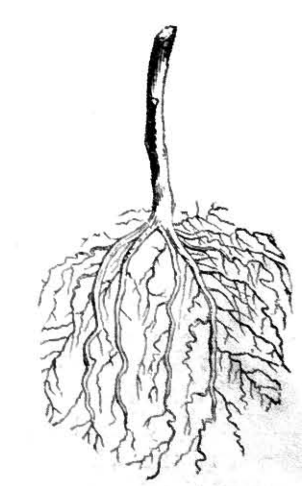
61. BROOD BASKET.



62. CIDER PRESS.



63. ARTIFICIAL MOTHER. (*Improved form.*)



64. THORN-PLANT PREPARED FOR PLANTING.

The orchard is liable to the inroads of various enemies, one of the most formidable of which is called "American blight" (*Eriosoma mali*). It is a small wingless insect (fig. 57), which preys on the bark, and forms from its own body a covering of down or cotton, under which it carries on its work. It pierces the bark by means of a beak terminating in a fine bristle, which penetrates to the sap and extracts it as with a syringe. The sap-wood, thus wounded, rises in knots all along the branch, and these, with the cottony appearance, are tokens too well known to the gardener that his trees are infected with multitudes of this kind of blight (fig. 58). The remedy is to clean every part of the bark with a hard brush and some searching wash, or, when the blight has penetrated too deeply to be removed with a brush, to varnish the branches with a mixture of resin and fish oil, which hardens on the tree and stifles the insects. Another great enemy to orchards is the Common Mistletoe (*Viscum album*, fig. 56), a parasitic plant, which fixes on the bark and lives at its expense. The seed being deposited by birds, a little rootlet issues forth, and takes fast hold of the bark, finally reaching the soft wood and obtaining all its nourishment from the sap. When two or three plants infest one branch, the latter withers away and dies, the parasites dying with it. To diminish this evil (which in the cider districts prevails to an extent scarcely dreamed of elsewhere), a labourer is sent among the trees in frosty weather, when the mistletoe is brittle, to pull off the plants with a hook, thus clearing fifty or sixty trees in a day.

When the crop of the cider-orchards is ready to be gathered in, the trees are generally beaten with poles (this is called *poulting*), and the whole of the apples are thus obtained at once; but a better plan is to send men into the trees, either to gather or to shake down such apples as are ripe (fig. 59), leaving the remainder for a subsequent operation. This gives more trouble, and is therefore the less general plan; but it saves the young wood of the tree from the injuries inflicted by the poles. The cider is also improved by allowing all the apples to be equally ripe before the operation commences. The fruit should be kept till it is mellow. To hasten this process, it is usually placed in heaps of about a foot in thickness, and exposed to the sun, air, and rain. The experience of the cider-maker enables him to judge when the apples are in the best state for his purpose, and he then causes them to be ground in a horse-mill, or a hand-mill, according to the quantity to be made. The hand-mill (fig. 55) consists of a pair of toothed wooden rollers, or preferably, a pair of fluted iron ones, with a feeder at the top and a handle at the side. The cylinders can be so adjusted as to reduce the pulp by degrees, so that at last scarcely a pip can pass unbruised. The pulp is called "must," and the juice is pressed out of it in the following manner:—A large horsehair cloth is spread out on the cider press (fig. 62), and some of the must poured into it from a pail. The ends of the cloth are then folded over, and another is laid upon it, and filled with must in a similar manner. Ten or twelve hair-cloths are thus filled, and the ends neatly turned inwards, after which a heavy wooden frame is placed on the top, and the screw slowly brought down upon it by means of a lever. A thick juice soon begins to pour out on all sides from the hair-cloths, and, after a time, nothing is left in the cloths but dry must. This is sometimes ground up again with water, and the liquid pressed out of it as before. This forms the weak beverage called "water-cider," which is drunk early in the year. In the Devonshire cider-press, reed, or unthreshed straw, is used instead of hair-cloth. The cider is at once put into casks, where, in three or four days, it will begin to ferment; the thicker part of the liquor subsiding to the bottom, and the lighter becoming bright and clear. The bright portion is then drawn off into other casks, and this has to be repeated again and again, if active fermentation continue. Much trouble and difficulty occasionally attend the making of fine cider; hence the beverage is less common than, on account of its excellence, it deserves to be.

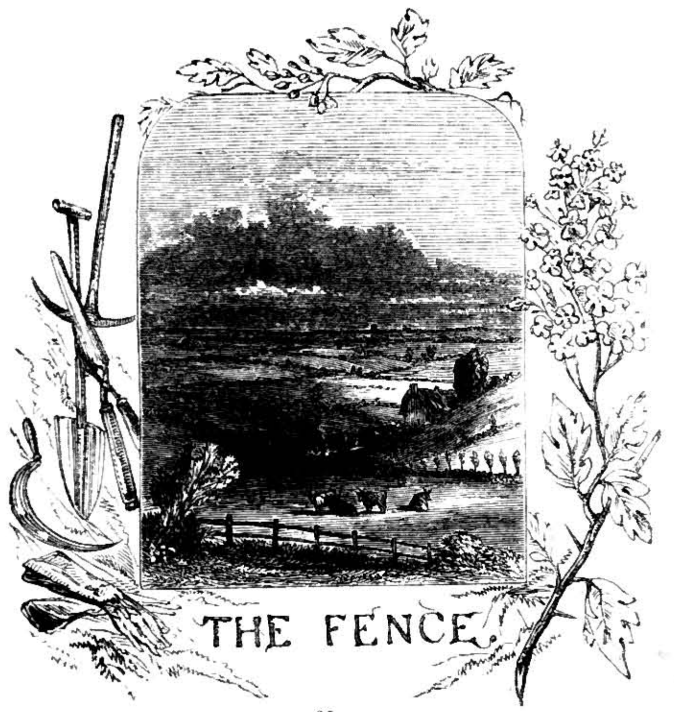
The Poultry Yard.—Although the rearing of poultry is an occupation chiefly carried on in the spring, yet the care of fowls is a business of the whole year, and we may chiefly allude to it here as one of the common operations of the farm. The Hen Coop (fig. 60) and its pretty little chirping brood form one of the prettiest sights of spring, and is the great delight of childhood. The old, rough form of hen-coop still exists, where the imprisoned hen vainly calls her wandering and scattered family; and where it would seem an especial cruelty to shut her up, did we not know that, in her zeal to find food for her offspring, she would infallibly lead them, were she at liberty, to distant and dangerous spots, where their lives might fall a sacrifice to some of their many enemies: for the fox, the weasel, the rat, and the pole-cat, are as fond of young chickens as any human epicure can be, and several of the young brood often fall victims to their rapacity, notwithstanding all the care which may be taken of them. When chickens first leave the shell, they require great attention; not only daily, but almost hourly. Fresh food should be taken to them every three hours during daylight, and water, in a very shallow dish, should be even more frequently renewed. Bread crumbs, finely crumbled boiled potato, groats, rice, and pearl barley, may be given in turn, in small quantities, and fresh every time. This done, and due precautions observed to keep them warm, clean, dry, and safe from their enemies, the chickens will generally be healthy, and will grow rapidly, becoming daily more able to provide for their own wants, and to forage for provisions in the neighbourhood of the coops. In Scotland, a hen and her chickens are sometimes carried out to the turnip-field, that the latter may pick up the larvæ which are so destructive to young turnip plants. For this purpose, a Brood-basket (fig. 61) is used. A large woollen cover keeps the chickens from escaping between the bars during the removal; but when this is taken off, they issue forth, leaving their mother, as usual, a prisoner. When they have exhausted the insects in one patch of turnips, the brood-basket is moved on to a new spot, the chickens following and proceeding with their task.

The difficulty of rearing a sufficient quantity of chickens in the natural way, led to the hatching of eggs by artificial heat, supplied by steam or dung, and the naturalist, Réaumur, invented what he called an "Artificial Mother" (fig. 63), in order to supply, as far as possible, the warmth and protection afforded by the hen. Boxes with sloping covers, lined with sheep-skin, the wool inwards, allowed of the chickens arranging themselves according to their size: the ends of the boxes were open to prevent suffocation. The boxes were placed at the end of a little feeding ground, the top of which was covered in by willow or wire. Several other forms were also employed, but none of these attempts to substitute artificial for natural heat appear to have been permanently successful. This contrivance was intended by its inventor to be useful for turkeys, pheasants, and other birds that do not go into the water.

In a large farm, the management of the poultry-yard is generally assigned to one person, and its duties may well be performed by a cleanly, good-tempered woman. The hen-house and hatching-house should be guarded from all other visits except those of this woman, whose familiar voice will not disturb the fowls. The hours for feeding poultry should be strictly observed, for they will never fatten or thrive properly with uncertain, irregular meals. Even what are called "barn-door fowls," which are supposed to pick up plenty of grain, are improved by a small daily meal, regularly given. The knowledge of the various kinds of food, which best suit the health of the different descriptions of poultry, and some acquaintance with the diseases common among them, are necessary qualifications in those who have the care of them. The vegetable diet of poultry is most extensive; but the principal dependence will always be on barley, wheat, and oats, the inferior samples of which are laid aside for the purpose. It is a pretty sight to witness the daily feeding of the birds. At the well-known call of their mistress, they come running and flying from every part of the premises with eager cluckings and cries, and great rustling of feathers (fig. 79). There assemble the lordly peacock, the stately turkey, the clamorous goose and duck, the pigeon, the ordinary fowl, and the guinea fowl. Outside all, or even boldly pushing in among them, are sparrows and other small birds eager to share in the booty. The value of fowls and their eggs, and the ready sale for them in all our great towns, make it a matter of surprise that these birds are not more cultivated by cottagers in the country. Their tendency to scratch and tear up gardens may be one reason for the small estimation in which they are held; but it has been said, that every cottager who keeps a pig should also keep fowls; their summer food being sufficiently provided for by a few potatoes and peelings, and the run of the pig's trough, and the winter supply being only a little oats, barley-meal, or Indian corn.

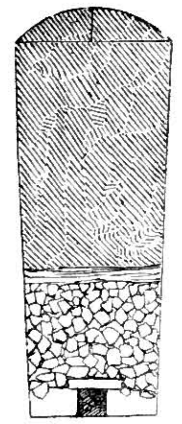
Hedging and Ditching.—Among winter employments which fill up any little leisure which may fall to the lot of the farmer, is that of looking to the fences. These form a great part of the beauty of an English landscape, and give the garden-like appearance which is so attractive to foreigners. On looking over a considerable tract of country, especially in the southern parts of the kingdom, the divisions of the fields, instead of being formal barriers of wood or stone, are undulating lines of living verdure, the rich dark green of which forms a beautiful contrast with the ripening crops, or a harmonious border to the tender green of the pastures (fig. 65). This fence almost universally consists of the common hawthorn (*Cratægus oxycantha*), which is the *aubépine* of the French, and the *Hagedorn* of the Germans, and which is too well known to need description, forming the "May" of our spring season, and the "haws" or red berries of autumn. Hawthorn plants are raised from seed in nurseries; but they do not germinate till the second spring, and it takes five or six years to rear plants which shall be useful in hedge-rows. A quicker way is to plant fragments or trimmings of the roots of older plants. These, if buried deep in rich earth, beyond the influence of frost, will sprout in the following spring, and grow quickly afterwards. A hawthorn fence is usually formed by the union of hedge and ditch, for which purpose a ditch is prepared by means of the ditcher's shovel (fig. 77), and the earth thus thrown up forms a mound, on the slope of which the hedge is planted, or rather a foundation for the good, well-prepared soil in which alone hawthorn plants will properly thrive. Fig. 64 represents a thorn-plant six or seven years old, cut back nearly to the root, which is the state to which it must be reduced in order to form the future hedge. But while the young branches are thus entirely lopped, the root is kept as nearly as possible entire, and its fibres are spread out on the prepared soil in their natural position. The stem need no stand more than two or three inches above the ground: it usually sends out three or four strong shoots near the earth, and thus prepares for that close and thick growth near the base, which is the chief value of a hawthorn fence, and which, with the stiffness of its branches and the sharpness of its thorns, make it nearly impenetrable. If the thorn is to be a really handsome hedge, it must not be mixed with other plants in the hedge-row, nor overshadowed by forest trees. The old hedges in many parts of the country, in which trees are plentifully mingled, while they afford a delightful shade to the green lane or the dusty pathway, and are very pleasant and picturesque objects to look at, are nevertheless disadvantageous by their shade and drip to the fields on the other side, and have, indeed, been stigmatised as "the landlord's thieves." Still, there are exposed situations where belts of trees, planted as shelter for the crops or live stock, are very valuable and effective. When hedges have become old and overgrown, and are thin at the roots, it is desirable to cut them completely down, and let them sprout out anew (fig. 72). But if there are considerable gaps at intervals, it is better to cut down one-fourth of the total quantity to the height intended for the fence, and then to bend and warp the remaining three-fourths of the upright stems, twisting them in amongst the rest, and thus supplying the gaps. This is called *plashing*. One of the most beautiful and durable of live fences is formed of the holly, but it is slow of growth, and requires protection until it has risen to a proper height; hence it will probably never become popular as a common farm fence, yet in some respects it would far surpass the hawthorn, being even closer of growth and more prickly, and having the great advantage of not losing its leaves in winter.

Draining and Irrigation.—Another business of the winter months is the restoring of old drains, and the forming of new ones in such portions of the land as suffer from superabundant moisture; and on the other hand, preparing for the conveyance of water to those which are in need of such enrichment. Stagnant water may either accumulate on the surface land, after heavy or long-continued rain or snow, or it may lie hidden far below the soil, being fed by secret springs, and giving no other token of its presence than the unhealthy character of the land and crops. The system of drainage, therefore, must be adapted to meet these opposite conditions, and must be either *surface-draining* or *deep-draining*, as the case requires. Surface-drains are of two kinds, *open* and *covered*: the former are mere gutters with sloping sides, made in the hollows and lower parts of land, and proportioned in size to the quantity of water to be carried off; the latter are trenches two or three feet deep, in which stones, rubbish, or draining-tiles are inserted, so as to keep a way open for the water to escape, while the earth is covered in on the surface, and no outward token of the drain is apparent, except in its effects. Sometimes a conduit is formed in a rough way by placing unhewn stones in such a manner as to leave a cavity at the lower part of the drain. Flat stones are laid along the top of this cavity, and other stones laid in above that, as shown at fig. 67; over this a layer of straw, heath, or furze, and then the soil, which is heaped up a little on the surface, because it always sinks afterwards. Another form of conduit is shown at fig. 73. But the work is more effectually performed by means of *draining-tiles*, which are of various forms and degrees of efficiency, and less liable to displacement than any mere arrangement of stones and rubbish. The draining-tiles may be of the shape which a common roof-tile would be, if we could bend it down at the two sides and make a half-cylinder of it; the objection to this form is, that when laid at the bottom of the trench, the two sharp sides resting on the clay, there is a tendency for the tile to sink, until the arch which it forms is quite filled up with clay, and the purpose of the drain defeated. To obviate this, a *sole* or flat piece is attached to the tile, as shown at fig. 83, but this increases the expense. In places where slate is plentiful, pieces of that substance are laid along the bottom of the trench, and the tile placed upon them, which prevents the sinking above referred to. But a contrivance now common, is that of uniting sole and tile in one, the tiles being made in the form of simple cylinders called *pipe-tiles*. Here there was the danger of their slipping apart at the joints, to prevent which, the ends of the cylinders were lobed, or made in a wavy line, as at fig.70, or they were embraced by a collar as at fig. 75. A cheaper kind of pipe-tile, however, is the tile and sole united, and of this also there are several varieties, one of which is shown at fig. 68. The manner of working is as follows:—A trench is made as before mentioned, and its sides and bottom are neatly finished off by means of the narrow *drain-spade* (fig. 66), and the *drain-scoop* (fig. 71). The workman stands constantly in the trench, an assistant hands him the tiles, &c., which he requires, and he fits them in their position at the bottom of the drain, securing them in their places by pressing the earth firmly round them and filling up the trench. The mouth of the main drain where the water is discharged, is protected by masonry and an iron grating. Smaller or branch drains are formed in the same way, with a very narrow drain-spade and smaller tiles. Deep-draining is the same in principle, but the drains are fewer, and much deeper, and more extensive. The work requires to be superintended by scientific hands, for deep-draining is a serious and expensive operation, and if carried on without sufficient knowledge and judgment, it may be mischievous rather than beneficial. Sometimes not even a drain of six feet deep will reach the seat of the water which is doing mischief to the land; it then becomes necessary to use boring irons, such as the common auger, a sharp, pyramidal punch, and a chisel or jumper (figs. 80, 81, 82), by which means the clay is pierced, and the water, if reached, wells up into the drain and so passes off. Some of the benefits of thorough drainage are thus described by a practical agriculturist:—"On drained land, the straw of white crops shoots up steadily from a vigorous braid, strong, long, and at the same time so stiff as not to be easily lodged by wind and rain. The



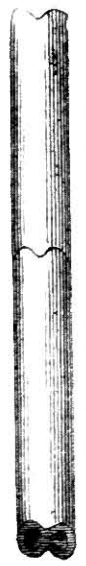
65.


66. NARROW DRAIN-SPADE.


67. DRAIN WITH CONDUIT.

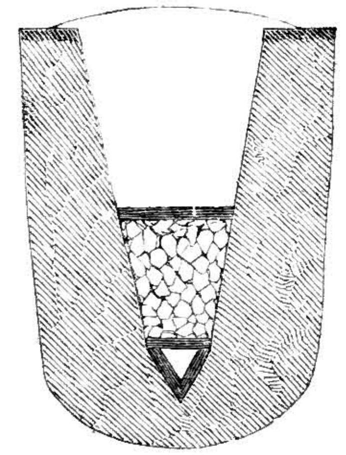

68. IMPROVED FORM OF PIPE-TILE.

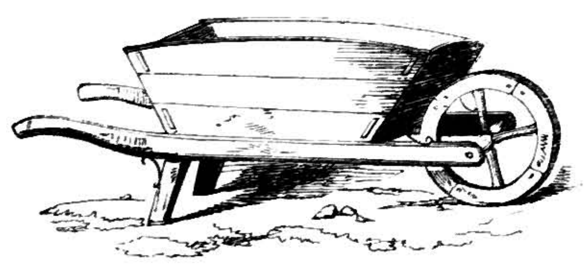
69.

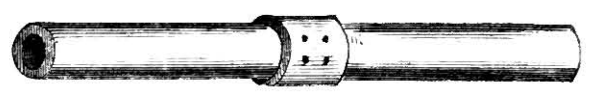

70. PIPE-TILE, WITH LOBED ENDS.

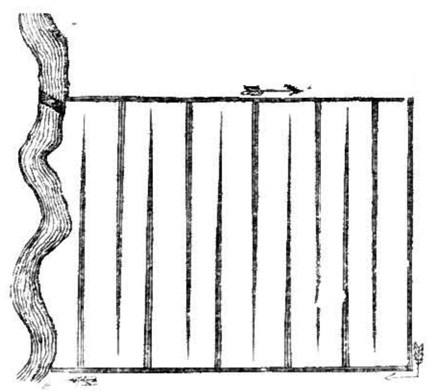

71. DRAIN SCOOP.


72. HEDGING AND DITCHING.


73. ANOTHER FORM OF CONDUIT.


74. BARROW.


75. PIPE-TILE, WITH COLLAR.


76. COMMON FORM OF WATER-MEADOW.

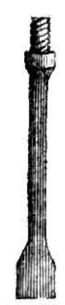

77. DITCHER'S SHOVEL.

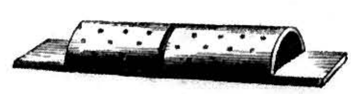

78. SECTION OF A RIDGE WITH FEEDER AND TWO DRAINS.

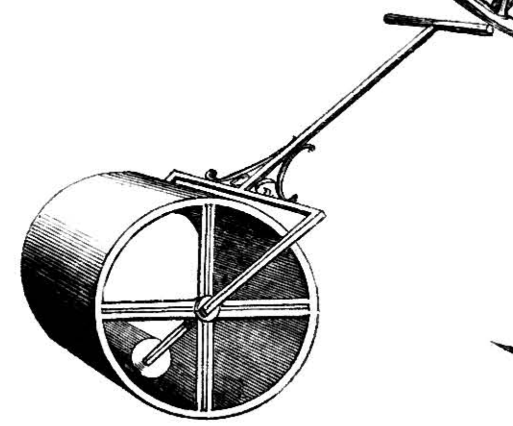

79. FEEDING POULTRY.

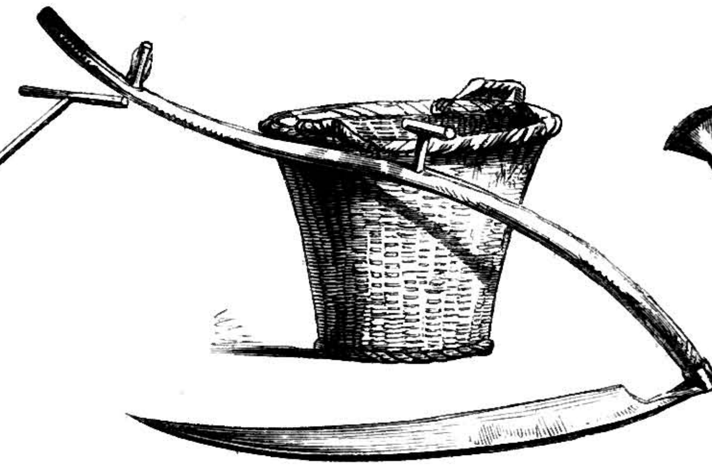

AUGER.

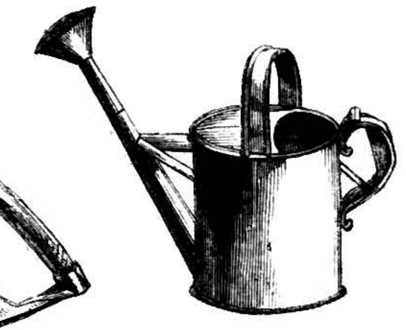

81. PUNCH.

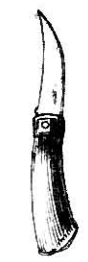

82. JUMPER.

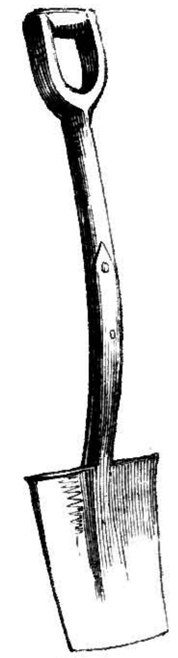

83. DRAINING-TILES, WITH SOLES.


84. ROLLER.

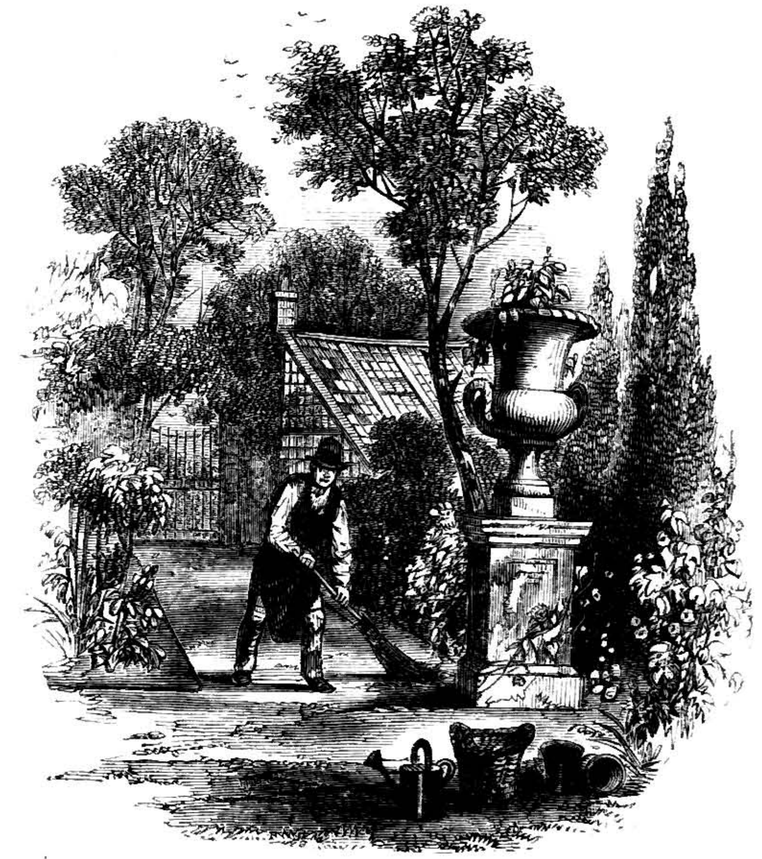

85. SCYTHE AND RUBBISH BASKET.

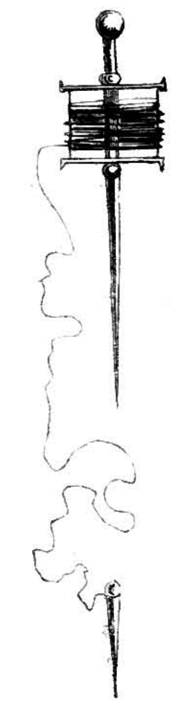

86. WATERING POT.

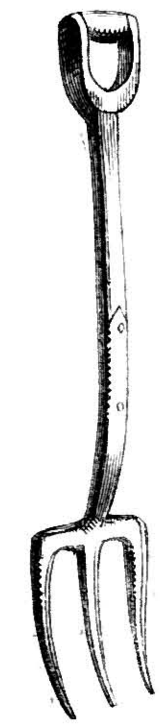

87. PRUNING KNIFE.


88. SPADE.


89. BUDDING KNIFE.

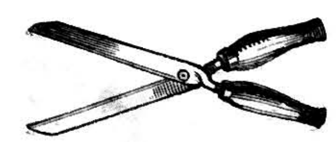

90. FLOWER GARDEN.

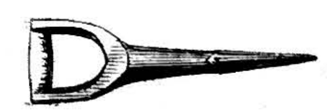

91. GARDENER'S LINE.


92. POTATO-FORK.


93. GARDEN RAKE.


94. TROWEL.


95. SHEARS.


96. DIBBLE.


97. HOES.

grain is plump, large, bright-coloured, and thin-skinned. The crop ripens uniformly, is bulky and prolific; more quickly won for stacking in harvest; more easily thrashed, winnowed, and cleaned, and produces fewer small and light grains. The straw also makes better fodder for live stock. Clover grows rank, long, and juicy, and the flowers large and of bright colour. The hay weighs heavy for its bulk. Pasture grass stools out in every direction, covering the ground with a thick sward, and produces fat and milk of the finest quality. Turnips become large, plump, as if fully grown, juicy, and with a smooth and oily skin. Potatoes push out long and strong stems, with enlarged tubers, having skins easily peeled off, and their substance mealy when boiled. Live stock of every description thrive, show good temper, are easily fattened, and of fine quality. Land is less occupied with weeds, the increased luxuriance of all the crops checking their growth. Summer fallow is more easily cleaned, and much less work is required to put the land in proper order for the manure and seed; and all sorts of manures incorporate more quickly and thoroughly with the soil." But it must be observed, that although such results as these follow the removal of *stagnant* water, yet the land requires constant supplies of moisture as the great means of nourishment and healthfulness. The rains which occur so frequently in our own country are in many cases sufficient to supply this want; but in parts of the world where rain only occurs at distant intervals, the land would become a barren desert were it not for the industry of the inhabitants in watering it by artificial means. In the neighbourhood of great rivers this is accomplished with comparative ease; and it has even been suggested that the overflow of such streams, and the subsequent fertility of the land which had been flooded, first gave the idea of artificial irrigation. In various parts of the world this art assumes an importance which it does not possess in this country, the growth and nourishment of the most important crops being dependent on it. In this country, water-meadows are indeed valuable, and a rich pasturage is thus supplied for our cattle; but irrigation is not required in order to make corn grow, or any other important crop of the year. The water-meadows of this country are managed with great skill, and the good effects of running streams instead of stagnant water have been fully proved. The manner in which they are arranged will be understood by consulting fig. 76, which represents one of the common forms of water-meadow. At the highest part of the meadow, a channel of considerable size is made, called the *main conductor;* this receives the water from the river, and distributes it over the meadow by means of channels or feeders at right angles with the main conductor. All these channels only provide for bringing the water into the meadow, but there is another and similar set of drains for carrying the water back into the river, so that between the two a constant flow is kept up. The feeders are formed on the top of low ridges (fig. 78), the drains in the hollows; and to keep the water at the necessary level, not only is its admission from the river regulated by a hatch (fig. 69), but smaller hatches or stops are placed in the feeders to interrupt its course. In forming these channels and drains the ditcher's shovel (fig. 77) again comes into use, and the earth dug from the trenches is wheeled away (fig. 74), to fill up hollows in other parts of the meadow. A barrier, called a *weir* or *dam*, is built across the river, in order to turn the water into the main conductor.

II.—THE GARDENER.

Akin to the operations of the Farmer, but on a smaller scale, are those of the Gardener, whose work is alike unceasing, and requires similar care and attention to render it successful. A great portion of his labour is indeed identical with that of the farmer, the only difference being in the tools employed. Instead of the plough he uses the *spade* (fig. 88), or the *potato-fork* (fig. 92); instead of the harrow, the *rake* (fig. 93); instead of sowing by the horse-drill, he puts in his seed by hand; and instead of collecting the fruits of the ground by scythe or sickle, he gathers them as occasion may demand, and leaves uninjured the stalks or branches on which they grow.

Digging, when well performed, is perhaps a more thorough disturbance and renewal of the soil than can ever be effected by the plough. The layer of earth is not simply turned aside, as in ploughing, but is completely turned over, so that the portion which has been partially exhausted by nourishing the plants, is brought to the surface; while that which has been renovated by exposure to the air, is sent down to supply fresh nourishment to the crop. *Raking* is again a more complete operation than harrowing, from the circumstance that the rake is not merely passed over the soil indiscriminately, but is worked backwards and forwards according to the judgment of him who wields it, stones being removed, while clods are broken by using the back of the rake to crush them. *Hoeing* is an expeditious way of removing weeds, and is performed either with the *common* or the *Dutch hoe*, both of which are shown at fig. 97. The common hoe has a flat iron blade fixed at the end of the handle, in the same position as the teeth of a rake. The Dutch hoe is a stirrup-shaped iron at the end of a long handle, and is used with less exertion than the former. Hoeing requires skill to remove weeds, and to leave the plants near them uninjured. The hoe must always be followed by the rake. *Planting* is performed by means of the *dibble* (fig. 96), when the plants are small, and is one of the most successful modes of cultivation; so much so, that in some places where labour is plentiful, it is adopted for field crops. In the smaller operations of the garden, where young plants have to be inserted in rows and at regular intervals, some other guide than the eye is required, and the gardener's *line* (fig. 91) is found useful in preserving the neatness and uniformity of the beds. This is a long line fastened to and wound upon a spiked reel, and having a spike also at the other extremity. The spike is driven firmly into the ground, and enough of the line is unwound to reach to the place where the line is to be fixed. The spike of the reel is here inserted, and the tightened line serves as a guide. Where plants require to have the earth kept about them during removal from one bed to another, the *trowel* (fig. 94) is a useful little implement; it also serves many other purposes, such as filling flowerpots with mould, &c., much more conveniently than the spade. *Watering* succeeds planting as a matter of necessity, and it should be sufficiently abundant to saturate the earth all round the plants. The *watering-pot* (fig. 86) should be furnished with two or three moveable tops, or "roses," with holes of various sizes for different crops; small and delicate plants requiring a fine spray, while larger ones will be all the better for a copious shower. As a general rule, watering should be performed in the evening, the plants thus enjoying its reviving effects for some hours before the sun returns to dry the soil. Plants growing in pots should also be thoroughly watered, but not allowed to stand in pans of water. Such pans are necessary to prevent injury in the house, but they should be emptied of water when it accumulates in them. The processes of *pruning* and

grafting, already spoken of in connexion with the orchard, are part of the gardener's work. The knives used are represented in figs. 87 and 89. Lastly, for the improvement of lawns and garden-paths, there are the *scythe* and *rubbish-basket* (fig. 85), and the *garden-roller* (fig. 84).

The skilful employment of all these auxiliaries produces the neat and orderly appearance so characteristic of our flower-garden (fig. 90). Not less orderly, nor less industriously kept, are the market-gardens in the neighbourhood of London, which supply that vast capital with its regular amount of vegetable produce. In these gardens, the ground is never allowed to remain idle; vast crops of cabbages cover the earth in October; when these are removed, celery and lettuce immediately take their place: after these come winter-greens, then (in spring) onions, more cabbage, cauliflowers, cucumbers, French beans, and scarlet runners. The enormous supplies required, make it a matter of astonishment that they are so equably and constantly met. Potatoes, at the rate of three thousand tons per week, and all other vegetables in proportion, are brought to the capital, and readily disposed of; and even such an insignificant article as watercresses is supplied at the rate of seven or eight hundred tons annually. No doubt the healthy state of the metropolis is greatly due to this constant and abundant supply of *fresh* vegetable produce, which the railway system also vigorously promotes by taking off again the overplus of the London markets, to be sold at a cheap rate elsewhere. Thus we were astonished on one occasion, to find in a city nearly one hundred miles from London, fruits from "yesterday's" Covent Garden market, selling at a rate which brought down the exorbitant demands of the country dealers in the same article.

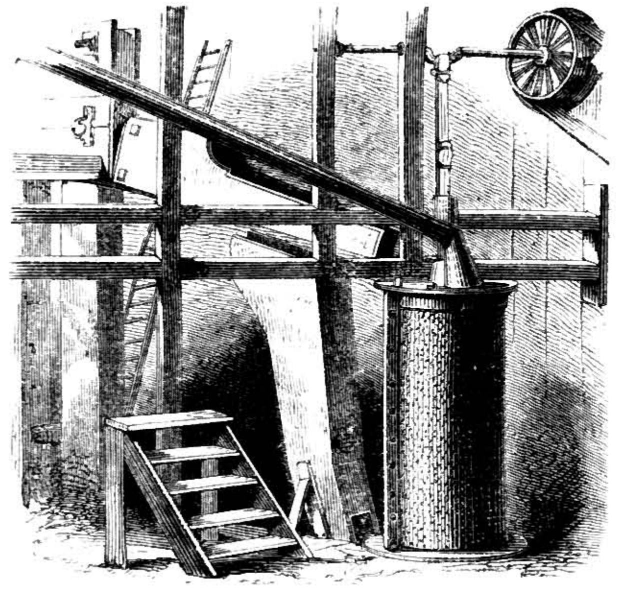
III.—THE MILLER.

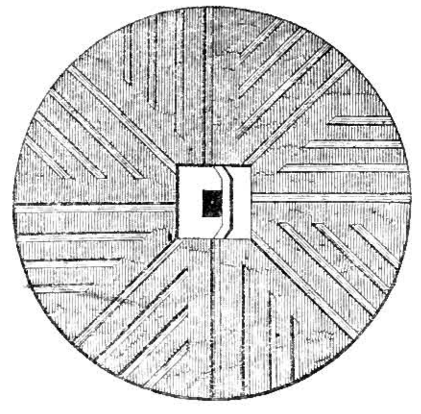
The trade of the Miller is important, since by means of it the first step is taken in preparing wheat for use. There is no article so well adapted for the food of man as bread. It contains all the ingredients necessary for forming and sustaining the three principal solids of the human body, viz. the fat, the muscle, and the bone; and hence it is that a wise Providence has scattered wheat so widely over the earth, that most nations are acquainted with it in some of its varieties. Wheat consists of starch and gluten, together with a little sugar and albumen. It is the business of the miller to grind the wheat to flour, and otherwise prepare it for its intended use; and the building in which he does this is often picturesquely situated by the side of a stream, commanding a head of water for turning the water-wheel which drives the machinery, as in fig. 108; or the mill may be situated on a hill or breezy down, where the wind gives motion to sails which drive the machinery, as in the common windmill; or, thirdly, if the mill be situated in a large town, and the operations be conducted on an extensive scale, the steam-engine is the prime mover.

The most essential part of a corn-mill is a pair of millstones, circular in form, and placed one above the other, but not sufficiently near to touch. The lower or *bed*-stone is fixed, and from its centre rises a spindle, on which the upper stone, called the *runner*, moves. This spindle is moved by means of cog-wheels in gear with it, and connected with the prime mover. In the centre of the upper stone is a hole, through which the corn passes to be ground. The flat faces of the stones are cut into furrows (fig. 99), which allow the flour to escape, as the wheat is ground by the action of the stones. The stones are covered in by means of a large wooden case (fig. 100), opening at the bottom by means of a shoot into troughs (fig. 103) in the floor below.

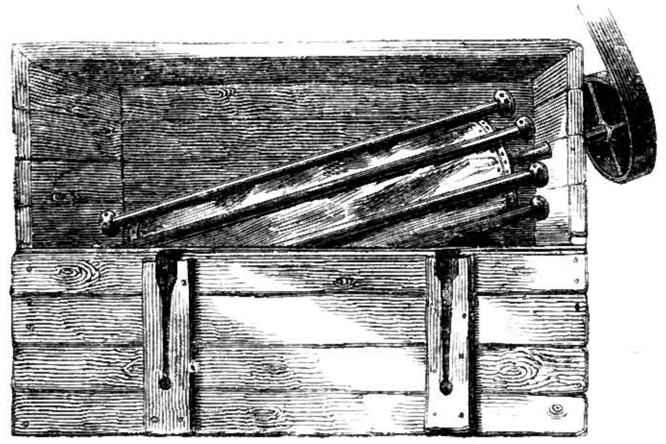
There are several varieties of flour used in London: they are known as 1. *Best Flour*, or *Pastry Whites*; 2. *Whites*; 3. *Households*; 4. *Number* 2, or *Seconds*; 5. *Thirds*; 6. *Fine Middlings.* There is also *dusting* flour, used to give a fine colour and texture to the outside of loaves. Each of the above varieties is produced by the admixture of several different kinds of wheat, well known to the miller, as the variety of flour is to the baker. For example: wheat containing much gluten may be mixed with one that contains an abundance of starch; a red wheat may be mixed with a white one; a moist wheat with one that is dry; and so on. The art of *mealing*, as it is called, consists in the judicious choice of the wheat, and in the proper arrangement of the machinery, so that the whole of the flour which the wheat is capable of producing may be obtained at one grinding. The proper proportions of wheat for grinding are mixed in a bin, after which the grain is passed through a blowing apparatus, in order to separate dust and light particles. It is next passed through a *smut* machine (fig. 98), consisting of iron beaters enclosed within a skeleton cylindrical frame covered with wire; the spaces being wide enough to allow the impurities of the grain to fall through. The beaters revolve 400 or 500 times in a minute, and by their action against the wires scrub the wheat, and remove portions of dust, smut, and impurities. After this, the wheat is passed through a screen, arranged spirally on a horizontal axis, the revolutions of which scatter the seeds over the meshes, and allow small shrivelled seeds to pass through. The grain is next exposed to a current of air from a fan, which completes the removal of chaff, dirt, smut-ball, &c. The result of all this elaborate cleaning is greatly to improve the whiteness of the flour, and also its wholesomeness; and its necessity is evident from the accumulation of impure matter in the cases of the screens. As the wheat passes from the last cleaning machine, it falls down a canvas tube into the hopper which supplies the millstones (fig. 100), where a jigging kind of motion is kept up, so as to shake the corn into the trough over the stones in equable quantities; and so long as this action is going on properly, a little bell is made to ring, the motion of which ceases with the supply of wheat.

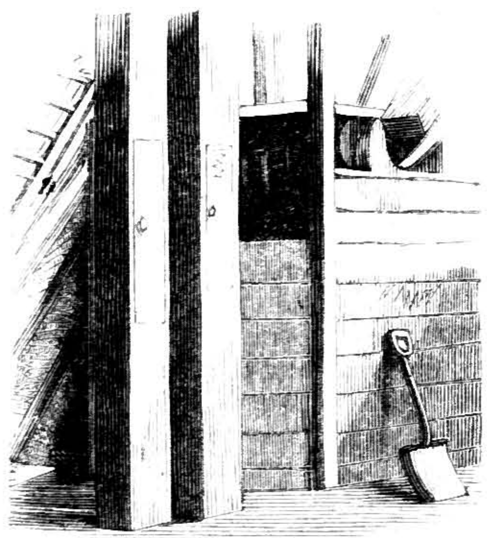
It has been already stated that the stones are boxed in to prevent the flour from being scattered by the centrifugal force of the runner. According to the old method, this is done very imperfectly, so that there is a considerable loss of fine flour; which fills the air of the mill, covers the men, and injures their health by being continually breathed. These evils are remedied by the improved method of grinding, represented in fig. 104. According to this plan, the stones are completely boxed in, and a blast of air is directed upon

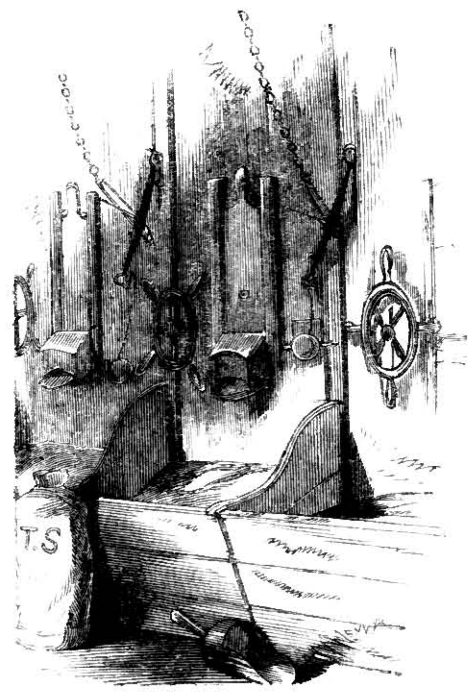

98. SMUT MACHINE.

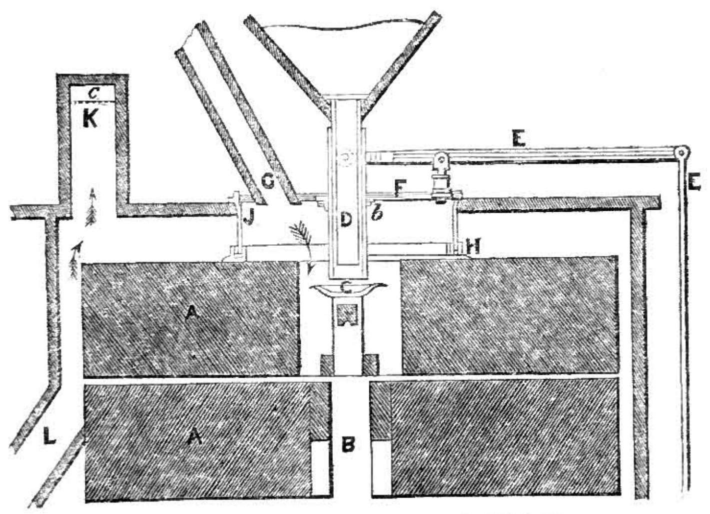

99. MILL STONE.


100. BOLTER.


102. THE BOLTING MILL.


101. REVOLVING SCREEN.

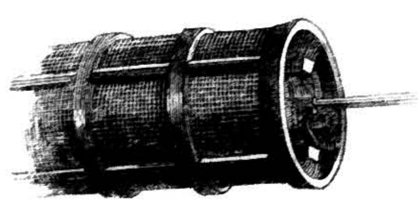

103. TROUGHS.



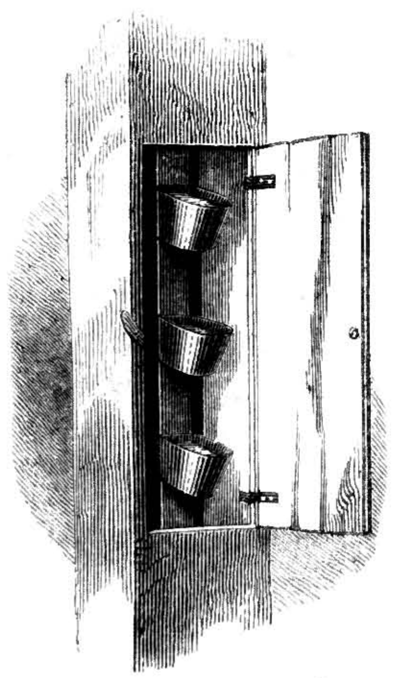
104. IMPROVED METHOD OF GRINDING.


105. CLAW.


106. SCOOP.


107. DRESSING MACHINE.


108. CORN MILL.


109. "JACOB'S LADDER."

the grinding surfaces for the purpose of keeping the stones cool, and removing the flour as fast as it is formed, the effect of which is that eight bushels of wheat can be ground per hour, while by the common method only four are produced; at the same time, the flour is improved in colour, and the usual waste avoided. In fig. 104, *A A* show the stones in vertical section, the lower edge of the runner at *A* being bevelled to admit the air-blast. *B* is the driving spindle on which the cup *C* is attached, for receiving and distributing the grain from the telescope feed-pipe *D*, which is regulated by a lever and rod *E*. The centre of the stone-case is closed by an iron plate *F*, with apertures for receiving the blast-pipe *G* and the feeding-tube *D*, a leathern ring at *C* making the joint tight. The blast is supplied to *G* by means of a fan or a blowing machine. At *H* is a grooved iron ring attached to the top of the runner, while at *I* is a circular leather inserted in the groove; the object of which is to prevent the blast or the grain from passing otherwise than through the centre of the runner. It will be seen by the arrows, that the blast must remove the meal as soon as it is produced, and send it down the shoot *L;* while any waste which would otherwise escape into the air, is collected in the waste air-pipe *K*. After the blast has served its purpose, it is conveyed into a closet lined with woollen cloth, through which the air filters, leaving behind fine particles of flour, which would otherwise escape into the mill.

The ground grain is usually separated into three parts, viz. the *flour*, the *pollard*, and the *bran*. The bran is the outer husk of the grain, and is given to horses and cattle; the pollard is the part next the husk, and is coarser and darker than the flour, which forms the interior or central portions of the grain. The meal is dressed or separated from the bran by means of the dressing machine (fig. 107), consisting of a hollow cylinder in a slanting position, covered internally with wire-cloth of varying degrees of fineness. Within the cylinder is a revolving reel with brushes attached; which, working against the wire-cloth, cause finer portions of the meal to pass through. The meal is usually conveyed from the lower to the upper part of the mill to be dressed. This may be done in sacks, or by the contrivance shown in fig. 109, called a *Jacob's ladder*, consisting of tin vessels attached to an endless band, which, filling themselves in the trough below, pass up a shoot, discharge their contents above, and descend to be filled again. The finest of flour passes through the upper end of the dressing machine, which contains the finest wire-cloth; the next finest flour passes through the next division, the *middlings* through the next, and lastly, the pollards, or *sharps*, through the last division; while the bran, being too coarse to go through any of the divisions, is discharged at the lower end of the cylinder. The apparatus is enclosed in a case, as in fig. 101, the lower part of which is divided into bins for receiving the different qualities of flour.

The dressing machine is an improvement on the *bolting mill* (fig. 102), which is still in use in rural districts. It consists of a long reel lined with a peculiar kind of cloth, made to revolve rapidly so as to be acted on by a number of bars, called *beaters*, which strike against the cloth, and cause the finer portions of the meal to pass through. In order to have flour of different degrees of fineness, different bolting cloths must be used. In the best mills, the meal is dressed by means of *silk machines*, each of which consists of an octagonal framework of wood moving on a central axis. The spaces of the framing are covered with silk of a peculiar texture. The ends of the machine are open; and the axis being inclined three quarters of an inch to each foot of the length of thirty-six feet, and the meal being poured in at the upper end, each of the eight sides of the frame acts in turn as a sieve as the frame revolves. In order to prevent the silk from being stopped up by the flour, the radial arms of the frame are furnished with stout rings of wood, which fall backwards and forwards between the axis and circumference of the frame as it revolves, and impart a vibratory motion to the silk, which assists the passage of the fine flour. The pollard, bran, &c., which do not pass through, fall out at the lower extremity of the machine, and are conveyed to other dressing-frames.

The flour which is separated from the dressing machine is a finished product; the middlings are passed through a bolting-mill, whereby three qualities are produced, viz. *fine middlings*, *coarse middlings*, and *thirds flour*. The first of these is used for sailors' biscuits, the second for feeding pigs, &c., while the third is sold as thirds flour. Seconds flour is produced from an inferior wheat. The *refuse*, or *offal*, is passed through a *jumper*, or frame of wire-gauze, of various degrees of fineness, whereby it is separated into *superfine pollard*, *fine pollard*, *coarse pollard*, and *bran*. Bran is generally supposed to give the colour to *brown* and *seconds* bread. This does not seem to be the case. The colour has been traced to a ferment in the starch even of the whitest flour. If this fermentation be checked by the use of salt, white bread can be made from the coarsest flour.

The advantage of the improved method of grinding (fig. 104) is that, by keeping the meal cool, it can be immediately dressed; whereas, by the common method, it has to be kept in sacks for some weeks before it is fit for dressing. In carrying a sack, the man assists himself by means of a *claw* (fig. 105), while the *scoop* (fig. 106) is used in weighing out small portions of flour, or taking up samples of grain.

IV.—THE BAKER.

THE baker procures his flour from the miller; and the first operation in the making of bread is to mix the flour in the kneading-trough (fig. 114) with about half its weight of water, but the proportion varies with the quality of the flour. The baker kneads the flour and the water together with his hands and arms into a stiff paste called *dough*, with the addition of a small portion of *yeast* and salt, when he leaves the mass for some hours at a temperature of about 70°. During this time the dough swells up, or, as the baker calls it, the *sponge* rises. The reason for this is, that the sugar of the dough becomes decomposed by the yeast; and a gas called *carbonic acid* is set free at all points of the dough, and being imprisoned by it, the gas makes it swell and become porous. It is now cut into pieces by means of the knife (fig. 117), and weighed at the scales (fig. 110), and put into the oven by means of one of the *peels* (figs. 116, 120); the oven having previously been cleaned out by means of a net or *swabber* attached to the end of a pole (fig. 112). The dough is heated to between 450° and 500°, when the imprisoned gas expands still more and gives that lightness of texture which belongs to good bread. The effect of the heat is to drive off a portion of the water of the dough, 117 parts of which become 100 of bread; while the starch passes into the pasty condition. Although so great a heat is employed, the temperature of the crumb does not rise above that of boiling water, or 212°, but the external surface of the loaf gradually becomes dry and hard; it loses a further portion of its water, and forms the *crust*. The bread thus becomes fixed in the shape of a loaf. During the baking, the alcohol formed by the decomposition of the sugar is driven off.

On the Continent, *leaven* is sometimes used to make the bread rise instead of yeast. Leaven is a portion of the dough kept from a previous *batch* in a warm place, until it begins to ferment of itself. The decomposition thus begun, spreads through the mass, when it is kneaded with fresh dough. A kind of unfermented bread is sometimes made by mixing carbonate of soda and hydrochloric acid with the dough; the acid sets free carbonic acid, which gives lightness to the bread, while the resulting chloride of sodium takes the place of common salt, with which it is in fact identical. The following proportions may be used for this kind of bread:—Wheat flour 7lbs., carbonate of soda 350 to 500 grains, water $2\frac{5}{8}$ pints, and hydrochloric acid 420 to 560 grains. The flour and the soda are first well mixed, and then made into dough by means of the water and the acid. In what is called *aërated bread*, water charged with carbonic acid is mixed with the flour under great pressure, and the resulting dough is at once fit for the oven. The great advantage of this process is that the laborious and often dirty method of kneading by hand is got rid of. But *kneading machines* are getting into use for ordinary bread. Pastry is sometimes made spongy and light by means of carbonate of ammonia, which is mixed with the dough instead of the yeast: the effect of the oven is to drive off the salt in the gaseous state, which produces the effect required.

In London there is a prejudice in favour of white bread, which is not, however, so nutritious as what is called *household bread*, from which only the bran has been separated. In order to produce white bread and to improve the tenacity of the dough of inferior flour, a small portion of alum is used. It has been pointed out by Liebig, that when flour has been injured in such a way as not to form good bread, the addition of a little lime-water will restore its good qualities, and get rid of that objectionable substance, alum. The baker is also in the habit of mixing potatoes with his bread, under the idea that it improves its quality. The quantity is usually not more than 8lbs. to a sack of flour, which weighs 280lbs., although in some cases a larger quantity is used.

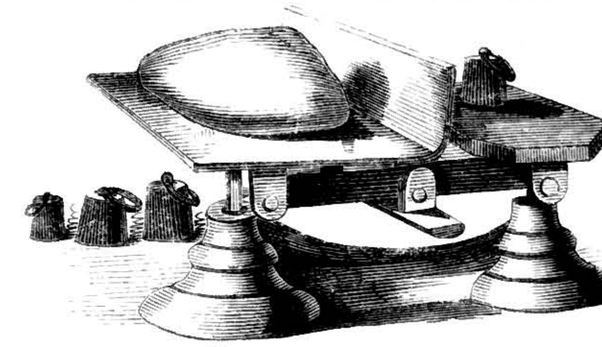
Newly-baked bread when cold contains about 45 per cent. of water, nor does stale bread contain a less quantity. Stale bread may be brought back to the condition of new bread by placing it in the oven for an hour. This effect may be seen on toasting a thick slice of stale bread, when the crumb will be found in the same state as that of new bread.

A sack of flour weighing 280lbs. and containing 5 bushels, generally produces 80 loaves. According to this, one-fifth of the loaf consists of water and salt, and four-fifths flour; but the number of the loaves depends on the goodness of the flour. Good flour requires more water than bad, and old flour more than new.

Fancy-bread is made of the finest flour, and is sometimes cut out into fanciful forms with a paste cutter, one of which is shown in fig. 118. *Biscuits* are also made into a large variety of forms. In large establishments, this is done by means of *moulding, stamping,* and *gauging machines*, which do the work with great rapidity. Biscuits are sometimes marked with a series of points (fig. 119), to allow the heat to penetrate better (the word "biscuit" being from the French *bis* and *cuit*, signifying "twice cooked" or "baked"): while some kinds of bread are baked in tins (figs. 122, 123). The hard dark crust of rolls is removed by means of a *rasp* (fig. 113), while a smooth glistening surface is given to other articles by means of egg or butter, the egg being beaten up with a *whisp* (fig. 115), and applied by means of a *brush* (fig. 121).

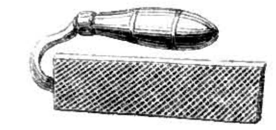
The *basket* in which the baker carries his flour is lined with tin, as in fig. 124, and the *scoop* with which he takes up small portions of flour is shown in the same figure. The *sieve* for sifting the flour (fig. 125) is made of wire, but he also uses a *seasoning sieve*, made of hair, for straining the water, the yeast, &c.

In London, the oven is heated by means of coals burnt in a fire-place on one side, and the heat is communicated by a flue winding round the oven. The baker judges that the heat is sufficient when some flour thrown on the floor of the oven blackens without taking fire. This is a clumsy method of proceeding, and the oven itself is not skilfully arranged so as to save fuel. Of late years, ovens heated by means of hot water pipes have come into use. They are clean and economical.

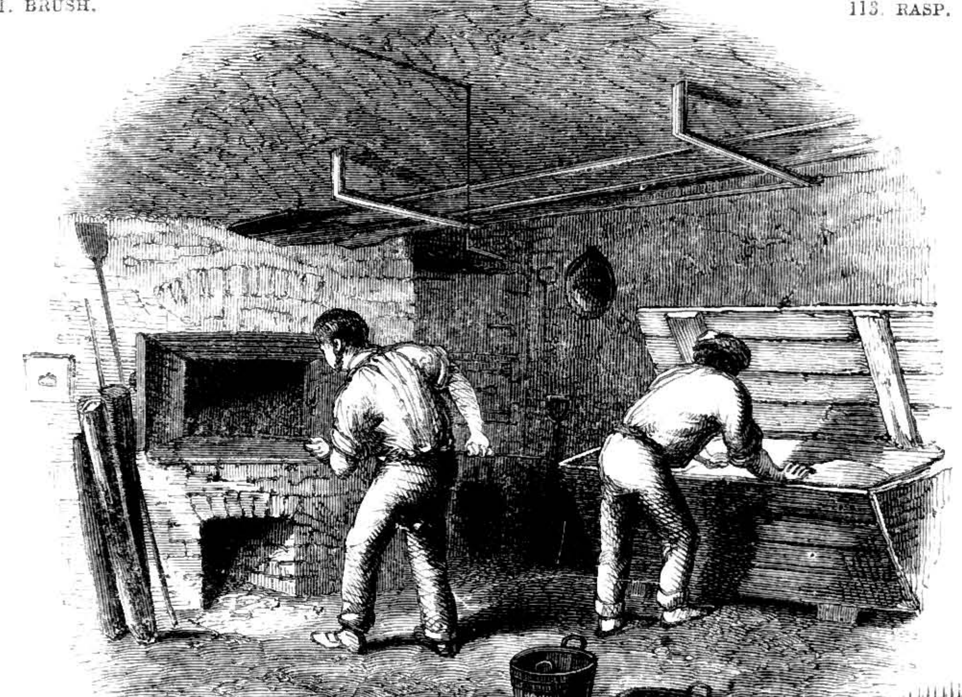

110. SCALES AND WEIGHTS.


112. CLEANING NET.


111. BRUSH.


113. RASP.

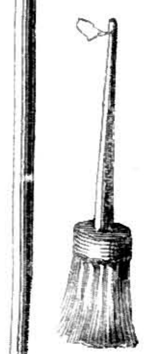

117. KNIFE.

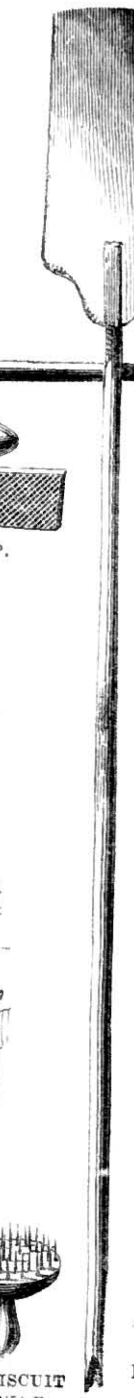

114. BAKING OVEN AND KNEADING TROUGH.


115. EGG WHISP.

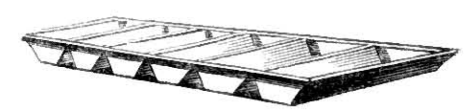

118. PASTE CUTTER.

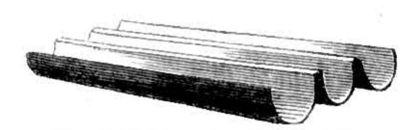

119. BISCUIT MARKER.


121. EGG BRUSH.

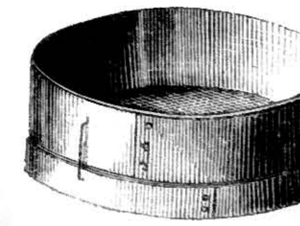

120. WOODEN PEEL.


116. IRON PEEL.


122. TIN FOR SPONGE CAKES.


123. TIN FOR FRENCH ROLLS.


124. FLOUR BASKET AND SCOOP.


125. SIEVE.

V.—THE BREWER.

Wine, beer, and such like drinks are prepared by the chemical process of *fermentation*, which is subject to many variations, according to the nature of the beverage intended to be produced. A few words, however, on fermentation in general will make the processes of the brewer, the wine-grower, and the distiller, more clear. By the process of fermentation, a particular change comes over saccharine bodies (or those which contain sugar), whereby they become converted into carbonic acid and alcohol. Thus, when the sweet juices of plants or of fruits—such, for example, as the *must*, or juice of the grape—are kept for some hours at the temperature of about 70°, they become turbid, small bubbles of gas rise to the surface, and the liquid is said to be *working*, or fermenting. The change produced in the liquid is, in the first instance, formed in certain albuminous and azotised matters contained in the juice, under the influence of the oxygen of the air, warmth, and moisture. As the fermentation goes on, heat is given off, and carbonic acid gas constantly escapes. After a time, the liberation of gas ceases; and if the liquid be examined, the sweet taste of sugar will no longer be found, but the flavour of spirits will have taken its place. If the liquid be now distilled, the first portions that come over will be an inflammable substance, known as *spirits of wine*. If the liquid be examined when the fermentation is complete, it will be found to contain a substance called *yeast*, which consists of a multitude of small, oval, organized bodies, not exceeding $\frac{1}{250}$th of an inch in diameter. This substance, yeast, is formed in great abundance during the fermentation of the *wort* of beer, and it possesses in the highest degree the power of producing alcoholic fermentation. If, for example, 4 parts of cane-sugar be dissolved in 20 parts of water, and 1 part of fresh yeast be added, and the mixture be exposed to a temperature of about 80°, fermentation will set in in less than an hour, and abundance of carbonic acid be disengaged.

In the preparation of beer, the sweet solution is formed by means of *malt*. Malt is prepared from barley, which is put into large cisterns containing water, where, absorbing moisture, it swells, and gives off carbonic acid. It is left in the water for about forty hours; after which it is taken out, and spread upon the malt floor in rectangular heaps, called the *couch*. Here it remains about twenty-six hours, during which time it increases in temperature, and parts with much of its moisture. In about sixty hours more, germination will have commenced: small roots appear at the bottom of each seed, and they would rapidly increase in length, unless their growth were checked. For this purpose, they are spread out upon the floor and turned over several times a day, in order to lower the temperature. In about twenty-four hours, the rudiments of the future stem, called the *acrospire*, begin to appear. When this has come nearly to the extremity of the seed, the germination is stopped by drying the malt in a kiln. It is spread out on a floor of iron plate, drilled with holes, while below this is a charcoal or coke furnace, and the hot air ascending through the floor, dries the malt and destroys its vitality. The malt is then passed through a screen, to separate the radicle; after which it is spread out so as to become soft and mealy by the absorption of moisture.

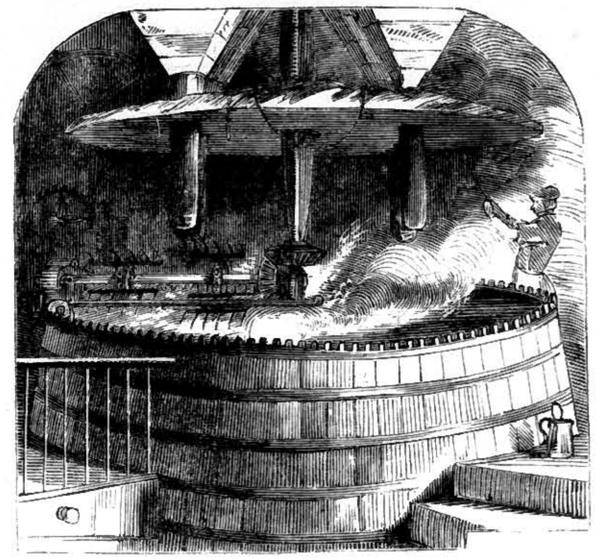
In the process of malting, sugar is not actually formed, but a peculiar azotised substance, named *diastase* (from a Greek word, signifying "to separate"), which possesses the remarkable property of converting the starch of the seed into a fermentable sugar, resembling cane-sugar, but not identical with it. This change, however, does not take place all at once; the starch is first converted into a gummy, mucilaginous substance, soluble in water, named *dextrine*, which does not ferment in the presence of yeast, but by the action of diastase becomes converted into starch sugar, which does ferment.

The next important ingredient in the preparation of beer is the *hops*. These are the seed pods of the female plants of the *Humulus lupulus*, a creeping plant of the family Urticeæ. It is cultivated in Kent, Sussex, and Hampshire. The active part of the plant, which is alone useful in making beer, is a yellow aromatic dust, formed at the base of the hop-flowers, or cones, and called *lupulin*. The cones are gathered before they are quite ripe, and are immediately dried in a kiln, at a heat not exceeding 86°. They are then strongly compressed by means of a hydrostatic press, and packed in canvas sacks, called *pockets*: the object being to exclude them from the air.

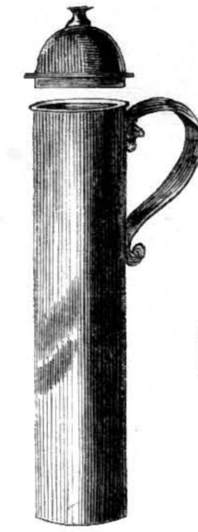
The first process in brewing consists in *grinding* the malt, which may be done either by means of mill-stones, steel mills, or iron rollers, the object being to crush rather than to grind; for if too fine, it would coagulate in lumps, and not be wetted by the water. The second process is called *mashing*. Water, at the temperature of from 160° to 170°, is drawn from the copper into a large vessel called a *mash-tun* (fig. 126); and when its temperature is ascertained by the thermometer (fig. 130) to be about 160°, a quantity of the crushed malt is shaken in, sufficient to absorb nearly the whole of the water, when it has been well stirred up by means of poles or oars, or of appropriate machinery, moved by the steam-engine, as shown in fig. 126. There ought to be enough water to wet the malt thoroughly, and to cause it to swell so as to dissolve the sugar, and to allow the diastase to react on the starch. When the malt has been completely wetted, the mash-tun is covered up, and left for about half an hour, when a second quantity of water at about 194° is added, with fresh stirring. The mash-tun is again covered up, and left for two or three hours. The liquor, now called *sweet wort*, is strained off into a vessel, called an *underback*. Water at 194° is again added to the mash-tun, forming what is called the "second mash," and, when drawn off, it may be added to the first. The water for the "third mash" may be near the boiling point: this removes all the remaining soluble matter, and when drained off is usually set aside by itself for making small beer. The mash-tun is commonly furnished with a false bottom, perforated with a multitude of holes, and the tap for draining off the wort is set in the tub between the two bottoms.

After the wort has been drawn off, the spent malt retains about thirty-two gallons of water for every quarter of malt used. In the after processes of boiling and cooling, about forty gallons of water are lost for every quarter of malt, making a loss of seventy-two gallons of water per quarter; so that, if thirteen quarters of malt be used to produce 1,500 gallons of beer, 2,400 gallons of water will be required for mashing. To enable the brewer to brew beer of the same quality, he tests his worts by means of a *saccharometer* (fig. 129). It is a species of hydrometer, consisting of a hollow copper-ball, with a weight attached to the foot-stalk, and a flat, graduated stem proceeding from the upper part, and so adjusted that, on being placed in water, it shall sink to a certain line, called the *water-line*; but on being put into a liquid heavier than water, it does not sink so much; so that, if the instrument sink in two different worts to the same mark, the brewer judges those worts to be of the same strength; and if it sink to different heights, he is able to calculate by how much one wort is stronger than another. Fig. 128 represents the can used with the saccharometer for testing the different worts.

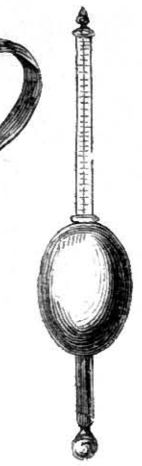
When the worts are adjusted to the proper strength, they are pumped from the underback into the copper (fig. 136), shown in section, fig. 131, while the stoke-hole of the furnace is shown in fig. 134. The copper is a close vessel, with a valve at the top, loaded so that the temperature may be somewhat higher than the boiling point of water, or 212°. As soon as the wort is introduced, the proper proportion of hops is added, and the boiling is continued until the mixture becomes clear. To prevent the hops from burning by settling to the bottom, the mixture is well stirred by means of a chain called a *rouser*, hung from a bar which is supported by an upright rod, passing out of the copper through a stuffing-box at the top, where it is in gear with the bevelled tooth-wheels by which it is driven (fig. 131). The quantity of hops used depends on the strength of the beer. For strong beer, four and a half pounds of hops to the quarter of malt are sometimes allowed. For the stronger kinds of ale and porter, it is usual to allow one pound of hops for every bushel of malt, or eight pounds to the quarter; but for common beer, not more than a quarter of a pound of hops to the bushel is allowed.



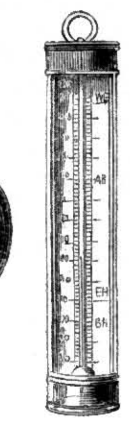
126. MASH TUN.



128. SACCHARO-METER CAN.

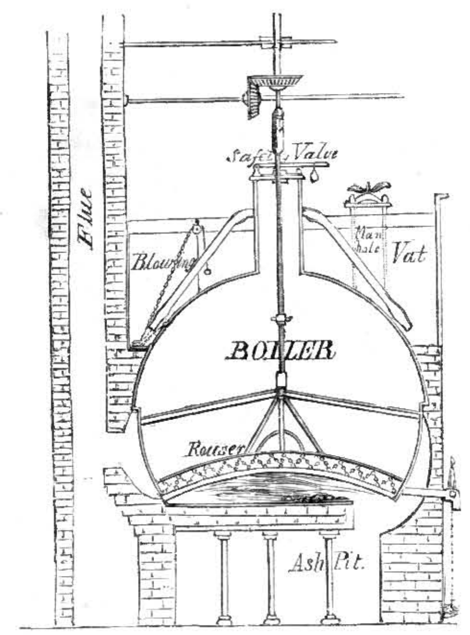


129. SACCHARO-METER.

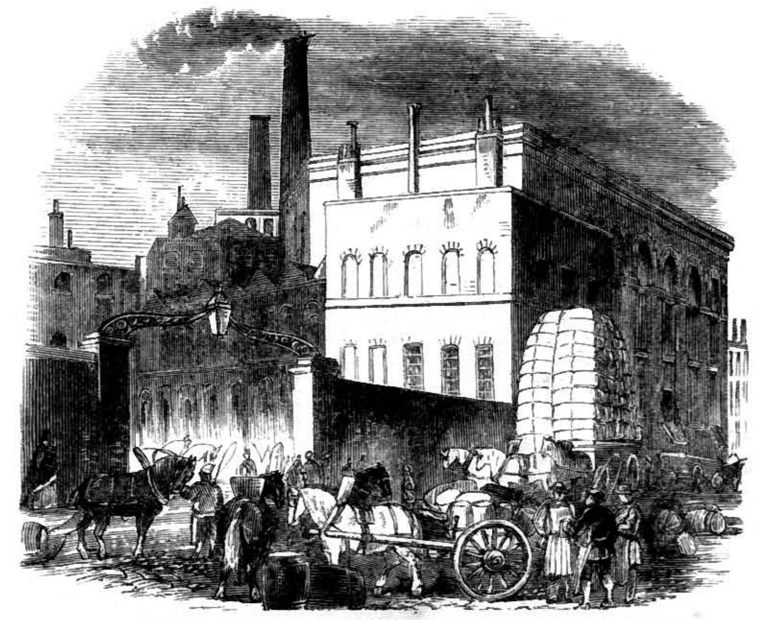


130. THERMOMETER.

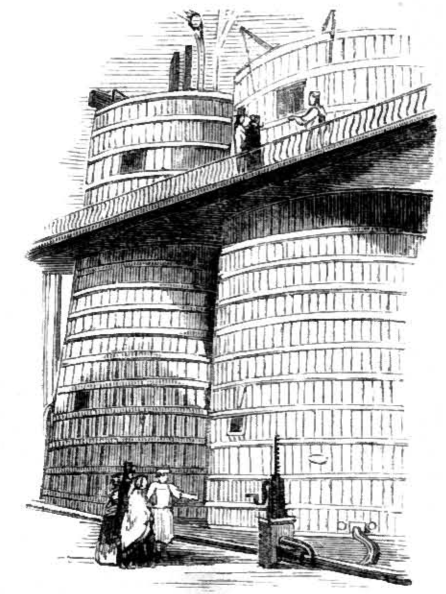
127. CLEANSING VATS.



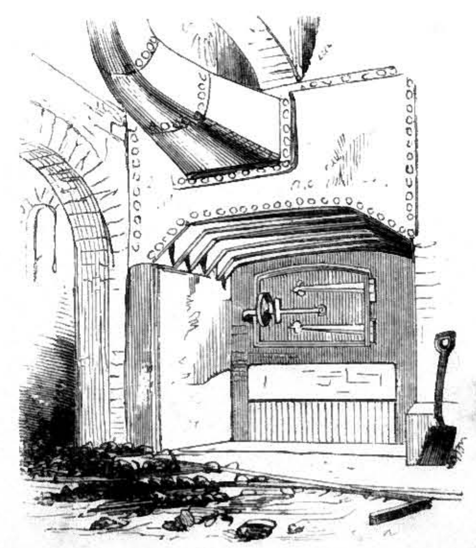
131. SECTION OF BOILER.



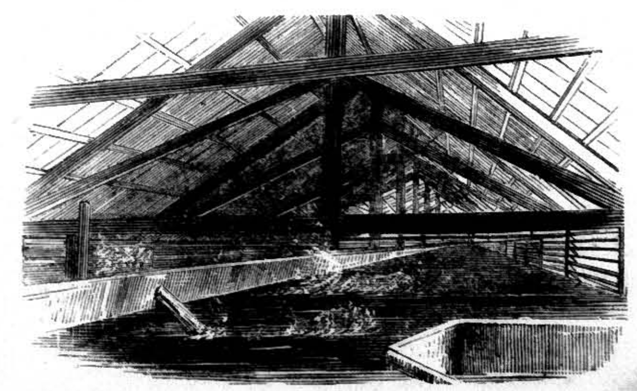
132. BREWERY.



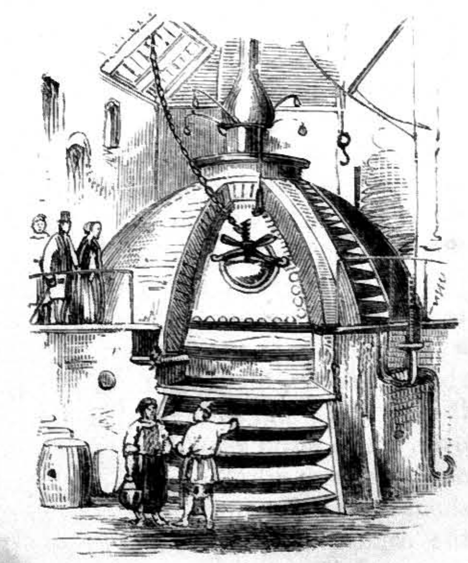
133. STORE VATS.



134. STOKE HOLE



135. COOLER.



136. TOP OF BOILER.

When all the bitterness of the hops has been extracted by the boiling, the worts are let down into a vessel with a metal bottom, full of small holes, called the *hop back*, where it is separated from the hops. The liquor is then pumped up into the *cooler* (fig. 135), which is a shallow vessel of considerable extent, usually situated at the top of the brewery, and exposed on all sides to a current of air; the object being to cool the liquor as quickly as possible, to prevent souring or *foxing*, as the brewers call it. In some cases, a large horizontal fan is made to play over the surface of the worts, to expedite the cooling. When the worts have cooled down to about 55° or 60°, they are received into a large vat called the *fermenting-tun*, where a quantity of yeast is added, varying with the strength of the wort and the time of the year; but usually one gallon of yeast is sufficient to produce fermentation in 100 gallons of wort. In the course of a few hours, a frothy ring may be seen to leave the sides of the tun, and to proceed a few inches towards the centre; this is succeeded by another and another ring, until, at length, the whole surface becomes covered with a thin, creamy froth. A slight hissing noise is also heard, owing to the breaking of innumerable bubbles of carbonic acid gas on the surface. The froth rises higher and higher, forming abrupt elevations, called by the brewer *rocks*. The colour of the froth passes from white to yellow, and often to brownish yellow. The froth becomes more viscid, and forms larger bubbles of gas, causing the head to foam and sink in turns. After some hours, the head begins to flatten and subside, and the thick yeast, having parted with its gas, would soon fall to the bottom, unless skimmed off. During this *vinous* fermentation, a portion of the sugar of the wort is converted into alcohol; but if the yeast were allowed to sink, the effervescence would soon cease, the liquor would become transparent, and soon after, a new set of changes would commence producing the *acetous* fermentation, and the liquor would be converted into vinegar. To prevent this, and to cleanse the beer of the particles of yeast which are floating through it, it is racked off into a number of casks called the *rounds* (fig. 127), in which the vinous fermentation is completed. During this operation, carbonic acid is liberated, and this, attaching itself to the suspended particles of yeast, carries them up to the bung-hole, where both are expelled. The bung-hole of each cask has inserted into it a short wooden pipe, terminating at the top in a sloping tray, which pours the yeast into a wooden trough, as shown in fig. 127. The rounds are kept always full, to facilitate the escape of the yeast. When the fermentation is over, the beer is pumped up from the rounds into immense *store vats* (fig. 133), (some of which contain upwards of 1,500 barrels,) where it is kept to ripen, or until it is drawn off into casks for sale. In the case of ale, however, the cleansing is carried on in the casks in which the liquor is sent out. When the cleansing is complete, the casks are bunged tightly down, to retain a portion of the carbonic acid, which gives to the beverage the brisk, foaming head, so much admired. The quantity of alcohol in common strong ale or beer is about 4 per cent.; in the best brown stout, 6; in the strongest ale, 8; but in common beer, not more than 1 per cent. Beer also contains gum, sugar, and starch gum in solution; also aromatic matters, lactic acid, various salts, and free carbonic acid, varying from 2 to 25 per cent.

In some cases, the cleansing is hastened by the addition of isinglass dissolved in weak, sour beer. When this *fining*, as it is called, is poured into the cask, it forms a kind of web over the surface of the liquor, and gradually sinking to the bottom, carries all the flocculent matter with it, and leaves the beer transparent. If this be required for keeping, it is usually racked off into a clean cask.

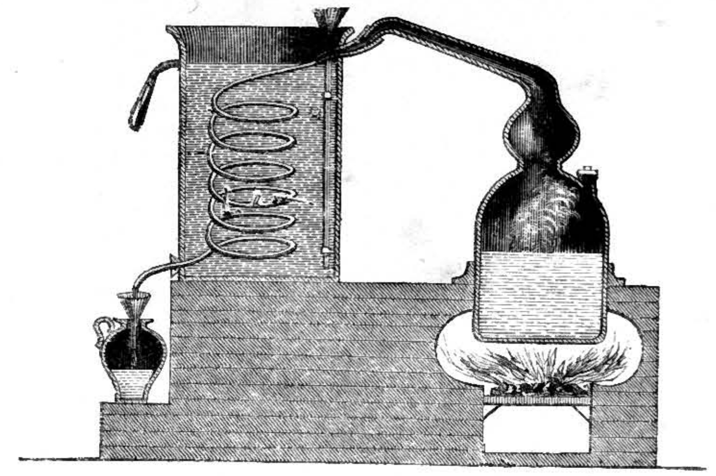
Porter brewing differs from that of ale in the quality of malt employed. In the former, a high-dried, partly-burnt malt is used; and in the latter, a pale malt. The methods of brewing also vary in different parts of the country; there are also slight variations in the nature of the materials, especially in the water, which give to different kinds of malt liquor their peculiar characteristics. Domestic brewing differs only from that of the large breweries in the quantities employed. In the latter case, these are so vast as to constitute quite a national feature. In the year 1864 the public brewers used 28,174,182 bushels of malt; licensed victuallers used 7,594,969 bushels; while small brewers used 3,218,476 bushels, and private persons 358,427 bushels. About 9,000,000 bushels were used by the distiller. The malt duty charged on 48,544,122 bushels amounted to 6,582,362*l*. In the year 1865, were exported from the United Kingdom 561,366 barrels of beer and ale, of the declared value of 2,060,369*l*. Our beer is sent to all parts of the world, even to Madagascar, Japan, and Siam.

VI.—THE DISTILLER.

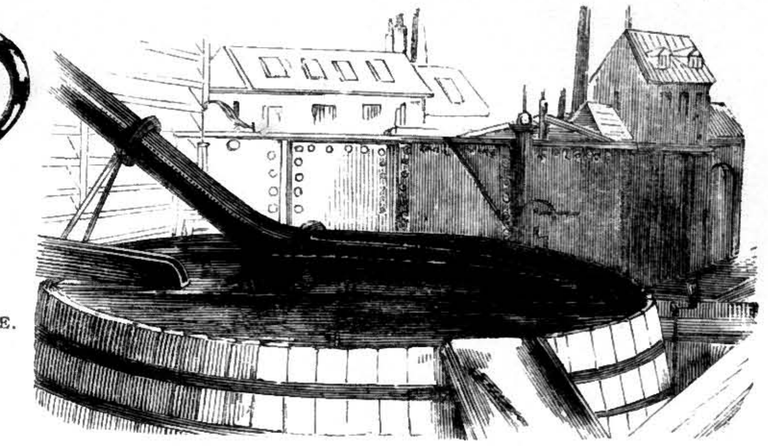
Distillation is the process by means of which one body is separated from another by means of heat. One of the bodies assumes the elastic form, or becomes converted into vapour at a lower temperature than the other, and is received and condensed in a separate vessel which is kept cold. When the vapour becomes condensed in the solid form, as in the case of camphor, sulphur, calomel, &c., the process is termed *sublimation*. Distillation is usually conducted in a *still* (fig. 137), which consists of a body, for the reception of the liquid to be distilled: a *head*, and a neck terminating in a spiral pipe or *worm*, which is contained in a vessel of cold water called the *worm-tub* or *refrigerator*. The body should be made so as to present a large surface to the fire, and its depth should be small. The neck should be tolerably wide, so as to convey away the vapour as fast as it is formed; and so high, that the liquid in the still cannot boil over. The worm should enter on one side of the tub near the top, and then pass spirally in six or eight turns to the bottom, where it should come out of the side so as to discharge the liquid formed by the condensation of the vapour within it. As the water in the worm-tub becomes hot by contact with the worm, fresh supplies of cold water should be admitted near the bottom, while the heated water is flowing away at the top.

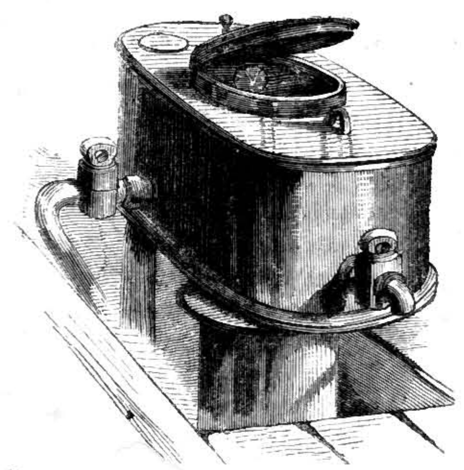
In the preparation of ardent spirits, the preparatory processes resemble in many respects those of the brewer. A saccharine solution or wort is made and fermented by means of yeast; but instead of allowing the spirit to remain in the liquor as in the case of beer, it is separated by means of distillation. In the different varieties of ardent spirits, alcohol, produced by the fermentation of sugar, is the intoxicating principle: the aroma, or flavour, which distinguishes one spirit from another, is due to the presence of an essential oil derived from the substance employed to furnish the saccharine solution. Thus the sugar-cane furnishes an oil which imparts the peculiar flavour to rum, which is obtained from the refuse of cane-sugar in the West Indies. So also the grape yields an oil which gives the flavour to brandy, and this is obtained by distilling wine in wine-growing countries. Gin, whisky, &c., are procured from malt or raw grain; the starch which forms a large proportion of barley is converted by the action of warm water into sugar, and this into alcohol. Grain contains a peculiar oil, most of which is separated during the rectification; but juniper berries are added in the case of gin, on account of their peculiar flavour.

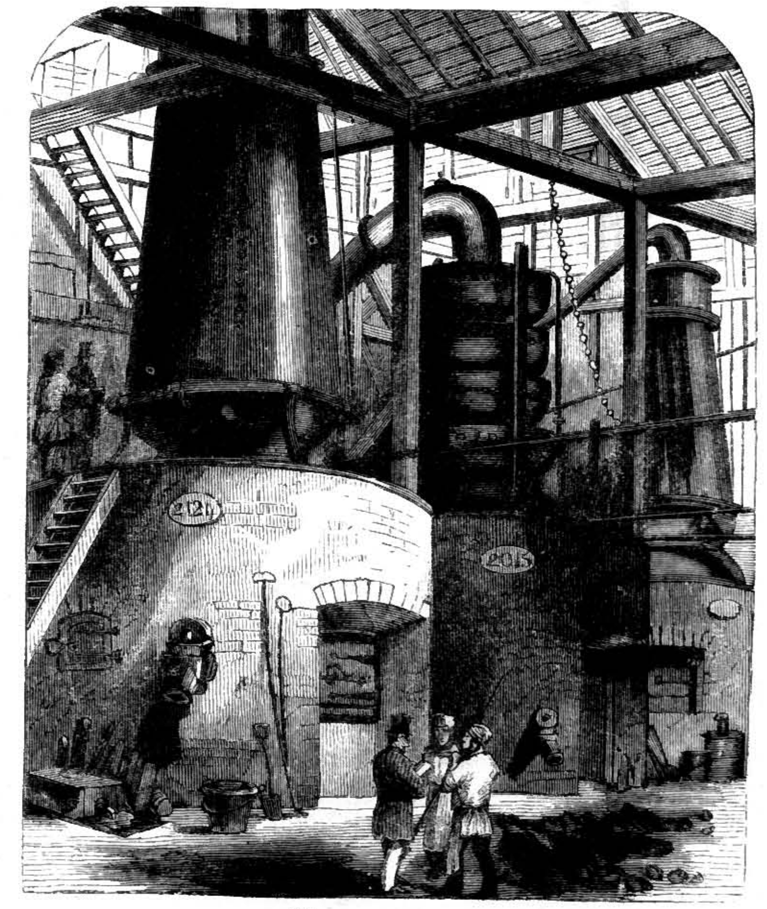
In the preparation of whisky, for example, barley is employed with malt in small quantity in consequence of the duty thereon. The grain is ground to a fine meal in a mill with a certain portion of oats, which are crushed or rolled, to prevent the barley-meal from clogging. A small quantity of malt is added to saccharify the starch of the barley and oats. The mash-tun is of cast iron, and the water

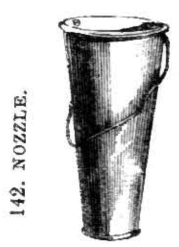

137. COMMON STILL.


138. SPIRIT GALLON MEASURE.


139. TOP OF WORM TUB.


140. END OF WORM OF RECTIFYING STILL.


141. DISTILLERY.

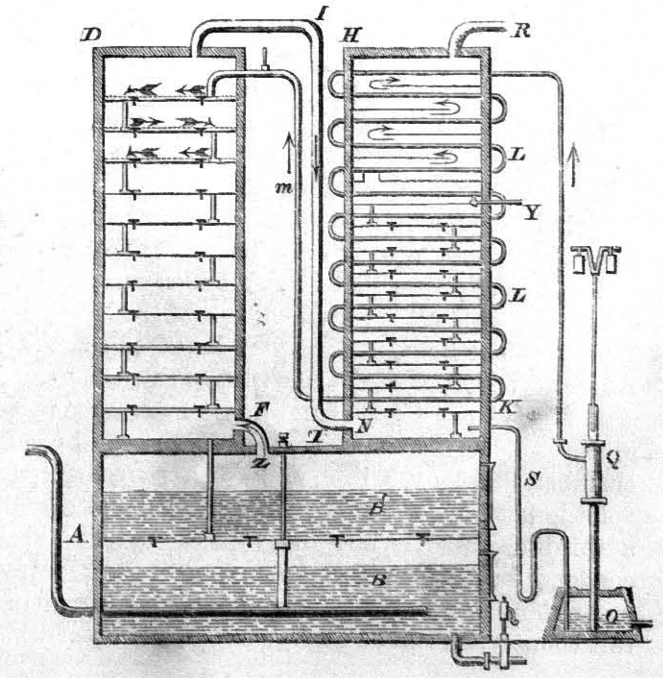

142. NOZZLE.



143. FUNNEL. 144. VELINCH.


145. PIPES AT THE WORM END.


146. STORE VATS.


147. COFFEY'S STILL.

measuring 700 or 800 wine gallons is let in at the temperature of 150°. The mashing is continued from one to four hours, and about 500 gallons of water at about 200° are let in from time to time to keep up the temperature. The wort gradually increases in sweetness until it is drawn off, which is done near the surface. Fresh water is added and left for about half an hour to infuse, when it is drawn off. More hot water is added, so as to get everything soluble from the grain. The wort is cooled as quickly as possible, and yeast is added to set the fermentation going. This process is carried on during many days, and the yeast is left in the liquor. As the fermentation proceeds, the specific gravity of the wort diminishes, owing to the decomposition of the sugar and its conversion into alcohol and carbonic acid.

When the fermentation is complete, the *wash*, as it is now called, is distilled. The still resembles that already described (fig. 137). Spirit being more volatile than water, passes over first in the form of vapour, and is condensed into a liquid in passing through the worm. The first portions are very strong, but as the process proceeds the heat vaporizes a portion of the water also, and this is condensed together with the vapour of spirit, and towards the end of the process more water passes over than spirit. When it is found by means of a hydrometer (fig. 145), that the condensed liquid is about as heavy as water, the distillation is stopped, and the cock at the bottom of the still is opened, and the wash is let off; it is a muddy brown liquor, containing a portion of undecomposed saccharine matter, and is used as food for cattle.

In Scotland the weak spirit obtained by the first distillation is called *low wines:* it contains about one-fifth of alcohol and four-fifths of water. The low wines are distilled a second time, when the first portion that comes over is called *foreshot;* it has a milky appearance and a disagreeable taste from the presence of oil; it is returned to the still, and it is not until the condensed spirit flows off transparent, that it is collected. When the spirit has reached a certain density, as determined by the hydrometer, the product is collected in a separate vessel. This third portion is called *faints*, and is mixed with the low wines, and distilled again. The distillation of the low wines is continued until the whole of the alcohol is of the proper strength.

In addition to the spirit and the water which pass over from the still, there are certain essential oils which vary with the kind of grain or vegetable matter employed. Those from wine, or from the wash made from sugar, have an agreeable flavour and aroma, but the oils from malt and grain are very disagreeable; and when the old form of still is used, it is the business of the *rectifier* to remove them. The rectifier procures the spirit from the distiller in the state of *raw spirit;* the still employed by him is similar to that used by the distiller, but he applies his heat with more caution. When the oil is abundant, alkalies are added, which form soapy compounds, which do not pass over at a moderate heat. Acids are sometimes added, by which the oils form resinous compounds, whereby they become less volatile. In the rectification of gin, a few juniper berries and some hops are added, to give a peculiar flavour to the spirit. The Dutch are celebrated for the manufacture of a kind of gin, known as *Hollands* or *Geneva*.

The vast quantities of spirits which are manufactured in the British Islands require a more complicated form of still than the simple apparatus already described, fig. 137. The process of rectification is costly: so that it was long considered a desideratum to complete the process of distillation and rectification in one operation. This was done by means of a still invented by a Frenchman, named Adam. The principle of his invention consists in connecting together a number of rectifying chambers, in such a manner that the vapour given off by the chamber nearest the fire shall condense in a second chamber, and by the heat due to its condensation cause the more volatile portions of the liquid in this second chamber to distil into a third chamber, while the vapours of the third chamber shall condense into a fourth, and so on, until the required degree of concentration is produced. This plan is carried out in the still used in this country, known as *Coffey's still*, a section of which is represented in fig. 147. *BB'* is the body, made of copper, and enclosed in a case of wood to preserve the heat. Rising from the body are two columns, *DF*, *HK*, while *O* is the vessel from which the liquor to be distilled is raised by means of a pump *Q;* the liquor enters the column *HK*, by the long spiral pipe *LL*, and after meandering through this is conveyed by the pipe *m*, in the direction of the arrow to the top of the column *DF*. The heat used for distilling is furnished by means of steam, which enters the body through the pipe *A*, the amount of which is regulated by a valve *F*. The body *BB'*, is divided into two chambers, by means of a copper shelf pierced with small holes, which allow the steam to pass upwards, but are too small to prevent much of the liquid from passing down through the shelf. The steam soon raises the liquid in *B* to the boiling point, first driving off the more volatile alcoholic portions. This vapour traverses the liquid in *B'*, raises it to the boiling point, and vaporizes the alcohol; which vapour passes off by a pipe *Z*, to the bottom of the column *DF*. This column is divided into compartments by means of perforated copper shelves, and each shelf is furnished with a pipe for conveying the liquid to the shelf below. Each pipe projects about an inch above the upper surface of the shelf, so that about an inch depth of liquor is retained upon each shelf, and is traversed by the vapours which ascend from the shelf next below it. The wash having become heated in its passage up the spiral pipe in *HK*, is delivered by the straight pipe *m*, to the top perforated shelf in *DF*, flows off at the further end of that shelf, and then falls upon the next shelf, from which it passes to the third, and so on to the other shelves; meeting, as it descends, the ascending vapours, which gradually become more and more alcoholic, while the wash, as it descends, becomes weaker and weaker; until, at length, when it arrives at the body *BB'*, it is wholly deprived of spirit. The shelves are also furnished with valves ⊤⊤, to allow the ascending vapour to pass, should the perforations in the shelves not afford sufficient space. When the vapour has reached the top of the column *DF*, it is conveyed by means of the steam-pipe *TTN*, to the bottom of the finishing column or rectifier *HK*. The lower part of this column, as high as the pipe *Y*, is constructed on the same plan as the column *DF;* but in each compartment, between the shelves the spiral pipe *LL* makes three or four turns, whereby it becomes warmed by the hot ascending vapours. In this second column, the alcoholic fluid distilled over from the first column undergoes rectification on each of the lower shelves, and becomes more and more concentrated by the ascent of the alcoholic vapours; which by being condensed at each successive stage, give out heat enough to distil the more volatile portions of the liquid by which they are condensed. The five upper shelves of this column merely act as a condenser for the alcoholic vapours: these shelves are not perforated, but are attached alternately to the sides of the column, so as to leave a narrow passage at one end of each shelf, and thus force the vapours to take a zigzag direction. The pipe *Y* carries off the finished spirit, while the pipe *R* conveys any uncondensed spirituous vapour to a refrigeratory, and the weak spirit which reaches the lower part of the column is returned to the vessel *O*. The spent wash, as it accumulates in *BB'*, is drawn off from time to time, so that the still can be worked without interruption. One of these stills at Inverkeithing distils 2,000 gallons of wash per hour, and there is one at least which distils upwards of 3,000 per hour. Some of the store vats (fig. 146) rival those of the London porter brewers (fig. 133); 20,000 gallons of whisky being sometimes stored in one vat. In some cases, water is distilled as well as alcohol, so that the latter is reduced to the proper strength by a suitable dilution supplied by the former.

The manufacture of spirits yields large returns to the revenue of the country, so that it is carefully watched by the officers of Excise to prevent illicit distillation. In the year 1864, there were returned for consumption in the United Kingdom 21,030,582 gallons of spirits; of which 5,041,714 gallons were exported. The duty amounted to 10,101,246*l*. Attempts have been made to diminish the consumption by imposing a higher duty on spirits, but these have always turned out to be failures; for where the poorer classes have been unable to purchase high-priced drinks, the smuggler and the illicit distiller have been ready with their untaxed spirits to supply the demand. The only safeguard for the poor against drunkenness is to be found in the active influence of the educated classes in pointing out the dreadful effects of this vice, in distributing books, in promoting parochial visitations, in opening churches to the parents and schools to their children; these are some of the measures which we may hope will, under the Divine blessing, tend to diminish a vice which is so extensive as to be a national curse.

VII.—THE BRICKMAKER.

"Let us make brick and burn them throughly," was the saying of the builders of the tower of Babel. (Gen. xi. 3.) This and many other proofs exist of the antiquity of brick-making, and of the employment of bricks in the earliest structures. Several of the pyramids of Egypt are built of bricks, and the walls of the most ancient cities were constructed from the clay dug out of their trenches and made into bricks. The Romans made great use of brick, and first introduced it, apparently, into our island. But it was not a favourite material with our people. Down to the time of the Great Fire of London, ordinary houses were made of a framework of timber, filled in with lath and plaster, or with panels of brick; and it was only after that fearful event that the great use of timber was discontinued, and brick became the prevalent material. Bricks, when well made, form perhaps the most durable of all building materials; but English bricks of the present day are inferior to many that are made abroad, especially in Holland, where the art has been brought to great perfection. Our materials are good, but the desire for cheapness in this country, and which is fostered by the metropolitan system of granting land on building leases, on the expiration of which the houses become the property of the landlord, tends constantly to encourage contrivances for saving labour and fuel, to the injury of the bricks.

Various argillaceous earths are employed in brick-making, but they are generally unfit for use without a greater or less admixture of some other substance. The purer the clay, the more likely is it to split in drying; and on the other hand, the lighter, looser, and more sandy the clay or loam, the more needful is a material to bind it into a compact mass. *Pure clays* are composed chiefly of one third alumina and two thirds silica, with small proportions of iron, lime, salt, magnesia, &c. Such clays are generally mixed with sand or loam. Other kinds of *brick earth* are the *marls*, or natural mixtures, of clay and lime: the *loams*, or natural mixtures of clay and sand. The loams require to be mixed with lime. There are many varieties of bricks. Bricks for common purposes are known as *place-bricks*, *grey and red stocks*, *marl-facing bricks*, and *cutting bricks*. The first two kinds are ordinary wall bricks, the *marls* are of superior quality for facing the outsides of houses, and the finest marls and red bricks are called cutting bricks, from their being used in arches, over doors, &c. and rubbed to a centre or gauged to a height. Certain foreign hard-baked bricks, called *Dutch* and *Flemish* bricks, and *clinkers*, are used for paving stable-yards, lining ovens, &c. Our Stourbridge clay is celebrated for the manufacture of fire-bricks. The *Dinas fire-brick* from the Vale of Neath, consists almost entirely of silica. The rock is powdered, and mixed with about one per cent. of lime, with some water, pressed into iron moulds, dried, and burnt. These bricks expand by heat, while bricks of fire-clay contract. They will bear a very strong heat without fusing, and hence are useful in furnaces, &c. *Ventilating bricks* and *hollow bricks* are now extensively made. They are larger and lighter than ordinary bricks, and, being perforated, take less material.

Whatever the variety of brick to be made, the clay must go through a long preparatory process. It is dug up in the autumn and left exposed to the mellowing influences of frost, snow, and rain. Frequently during the winter also, the masses are broken up and turned, so that the atmosphere may penetrate them in every direction. In the spring, the clay thus broken up is thrown into shallow pits, where it is soaked with water and tempered. But for the superior bricks used for the outside of houses, the plan is different. The clay, in this case, is ground to pulp in a *wash-mill* (fig. 148) as soon as it is dug in autumn, and is mixed with chalk previously ground and made into a creamy liquid with water. The mixture thus formed is allowed to run off through gratings, and settle until it is firm enough for a man to walk upon; it is then covered with finely sifted ashes, and left all the winter to mellow. In the spring, the clay is dug up with pick and shovel (figs. 156, 158) and the ashes are thoroughly mixed with the clay, and pugged in a *pug-mill* (fig. 149). This is a conical wooden tub, with a vertical revolving shaft passing through it. On this shaft are placed a number of knives, which cut and knead the clay, and force it through the mill, which is filled at the top from the barrows of the work-people (fig. 153), and has a hole at the bottom where the clay issues forth and is cut into pieces and piled up for use. Where the demand for bricks is large, the pug-mill is indispensable, but in many country places the kneading and tempering of the clay is still performed by the naked feet of the labourers, which, from long practice, become sensitive to the presence of the smallest stone or roughness which interferes with the uniform texture of the mass.

The clay, being by this means brought into the necessary state for brick-making, is next conveyed to an open shed in the brick-field (fig. 157), where the moulder, with an assistant, stands at his bench, rapidly converting the plastic material into bricks. At such a bench the writer often used to stand for hours, as a child, watching the moulder, and receiving gracious permission occasionally to help in the work, the practical details of which became thus perfectly familiar. On the moulder's bench were placed a trough of water, a heap of sand, a pile of boards called *pallets* (fig. 154), and a *mould* (fig. 152). Floating on the surface of the water was a *strike* (fig. 151), which, in our case, was only a smooth strip of wood rounded at the ends, without the opening for the hand shown in the figure. Fixed to a convenient part of the bench, was a board exactly the length and breadth of the intended brick; this was called the *stock-board* (fig. 150). The first thing the moulder did, was to take up the mould (fig. 152), a frame without top or bottom (now generally made of brass or iron, but in former days of wood), and dash it into the heap of sand, so that it might be well sanded inside and out. He then placed it on the stock-board, which it fitted exactly, and yet so easily as to give no trouble in adjustment, and slapped into it a mass of clay, rather more than enough to fill it; pressing down the mass so that it might fill every portion of the mould, there still remained an overplus, which was rapidly shaved off by the strike, or wet piece of wood close at hand, which was taken out of the trough for the purpose, and returned to it again almost in an instant. One of the pallets was then taken from the pile, dashed into the sand-heap, and laid on the top of the new-made brick in the mould. The mould was turned over, and the brick thus transferred to the pallet was ready to be carried away on the *hack-barrow* (fig. 155). The pallets are of the same width as the mould, but a little longer; six-and-twenty pallets form a set, and three sets are required by each moulder. The hack-barrow has a flat top of light framework, fit to receive two rows of bricks, thirteen in each row. Three of these barrows are kept in constant use by one moulder. One barrow stands at his side and is rapidly filled as he makes the bricks, another is unloading in the drying-ground, and the third is being wheeled back from the drying-ground, to take the place of that which is being filled. In the drying-ground, a succession of long, level, well-sanded paths of earth, a little raised above the rest of the field, afford space for the bricks, which are built up in *hacks* or low walls, two bricks wide and eight bricks high, with spaces between for the passage of currents of air. The bricks are placed at first in a single layer the whole length of two of these paths, so that by the time the end of the second is reached, the first is firm enough to allow of a second layer of bricks. The hacks are protected with straw or hay, or a thatched frame (fig. 161) at night and in bad weather. In some cases, drying under cover is adopted for very superior bricks, and flues are carried under the floor of the drying sheds to hasten the process. The outer air is then carefully excluded.

Rapid as are the movements of the brickmakers, they are not quick enough to meet the enormous demand for bricks of the present day. Machines have been contrived for moulding bricks, and these far outstrip human hands in speed, but do not produce equally successful results. Machine-made bricks are dense, and heavy, and, being smooth, the mortar does not adhere to them quite so well as to the hand-made; while their weight increases expense in carriage, and prevents the workman from laying so many in a given time. Still, however, the enormous demand for bricks in railway and other works, has called the brick-making machine into active use, on account of its superior producing powers. A description of such a machine will be found at the end of this chapter. It is a common practice at the present day to diminish the weight of bricks by hollowing them out beneath, and thus also leaving a bed for the mortar. In order to make these hollow bricks, it is only necessary to fix on the stock-board what is called a *kick* (fig. 150), which is a piece of wood elevated in the centre, and thus taking up some of the room in the mould which would otherwise be filled with clay. But there is another kind of hollow, or perforated brick, in which little tunnels are driven through the brick longitudinally, in the same manner and by the same kind of machine as in the drain-pipes used in agriculture (fig. 160). These bricks, from their mode of manufacture, are more compressed than ordinary bricks; they are also of larger size, so that nine hollow bricks will do as much walling as sixteen of the common sort, with only a slight increase in weight (fig. 159). Altogether, the advantage of the *patent bonded hollow bricks* over others is stated to amount to twenty-nine per cent., in addition to a considerable diminution in the cost of carriage or transport, and to twenty-five per cent. on the mortar and labour.

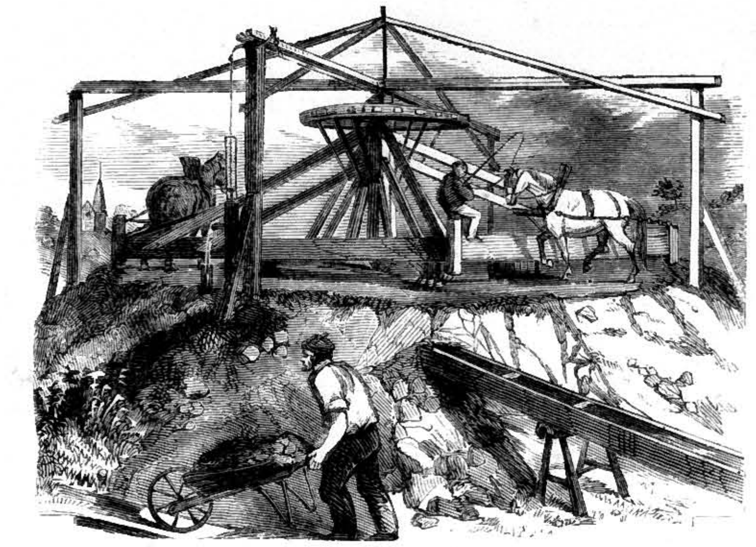
But our notice of the brick manufacture has only as yet conveyed the new-made bricks to the drying-ground. When sufficiently hardened, they are taken thence to the kiln, or *clamp*, to be burned. The kiln is the older and the better plan. It is usually a simple rectangular chamber, built of old bricks and rubble-stone, with a narrow doorway at each end, and fire-holes lined with fire-bricks at each side exactly opposite to each other. The workmen carry in at the doorways a quantity of bricks piled up on the barrow (fig. 162), and stack them loosely, but with considerable art, in cross-courses, from wall to wall, leaving openings that shall act as flues, and distribute the heat from top to bottom. When the kiln is thus filled with bricks, to the number of about 20,000, the top is covered in, and fires are lighted in the fire-holes. The heat is kept moderate for the first two or three days, that the remaining moisture of the bricks may be gradually evaporated; but when the steam ceases to rise, the heat is raised, the doorways are bricked up, and the temperature continued till the fire begins to appear at the top, when it is slackened, and the kiln allowed to cool. The heating and cooling are then repeated, and in about forty-eight hours the bricks are thoroughly burnt. The kiln is heated with furze, heath, brake, &c., or with pit-coal, as the case may be. The burning of bricks in a clamp is a much slower process—it occupies from two to six weeks; and the bricks in some measure supply their own fuel from the quantity of ashes (technically called *breeze*) employed in their manufacture. Layers of ashes are also added, as the bricks are built up into a central double wall, with other walls of brick on each side leaning against it, the whole being framed with considerable skill into an immense mass, or clamp, the sides and top of which are cased with burnt bricks, while numerous *live-holes* are left, which are fired in succession, the fuel being wood, coal, and breeze. The bricks are not in this manner equally fired, the outer ones being not burnt enough, while those near the fire-holes are burnt too much, and frequently run together in masses and are spoiled. Specimens of this fused brick may frequently be seen in the rock-work of suburban gardens.

Such is an outline of the process of brick-making, but there are variations in different parts of the country. Sometimes the clay is ground between rollers, instead of being passed through the pug-mill; sometimes the wash-mill only is used. The processes of moulding and drying are also far from uniform, and the form of the kiln is subject also to variation.

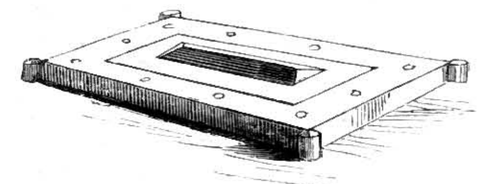
A method has been devised by Mr. Prosser, of Birmingham, of making ornamental bricks, floor-tiles, &c. of clay, nearly in the state of a dry powder. A strong pressure is given by machinery to the clay in metal moulds. This pressure reduces it to one-third its original thickness, and gives it sufficient compactness to be handled at once and taken to the drying-kiln.

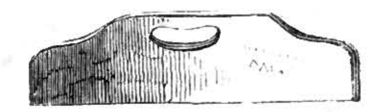
The manufacture of ordinary tiles, whether for covering the roofs of houses or for paving, is conducted on the same general plan as that of bricks: indeed, they may be considered as thin bricks. The mould is shallower, the stock-board is of a different shape, and the drying is performed on shelves of plank under a shed, instead of on the ground. Drain-tiles are made by machinery, which cannot be here described.

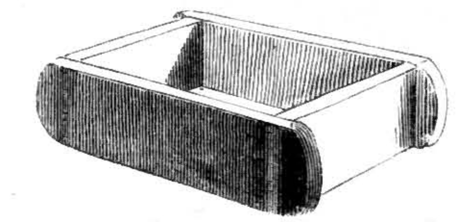
At the present day, the manufacturer, with his self-acting machines, is in so many cases superseding the mechanic with his hand-worked tools, that it is often difficult to give illustrations of trades without encroaching on manufactures. Thus, brick-making is both a handicraft and a manufacture. Brick-making machines may be arranged under two heads:—1. Those that work the clay while it is moist and plastic; and 2. Those that work the clay in a dry state. In the first class, the plastic clay is formed into a continuous length, by means of a screw, pugging-blades, or rollers, and is divided into bricks by means of wires moved across the clay ready for drying, before being burnt. Such bricks are not much harder than hand-made bricks. In the second kind of machines, the drying of the clay, and reducing it to powder, add somewhat to the cost. Mr. Oates has contrived a machine in which the clay requires but little previous preparation, unless it contain stones, which are got rid of by passing the clay through rollers. The accompanying figures will explain the action of this machine. The clay cylinder *AA* is of cast iron, and is expanded at the top, so as to form a sort of hopper for the clay, while the lower part is about the same in diameter as the length of the brick mould *F*, at the bottom of the pressing chamber *B*. The screw *C* is in the axis of the cylinder, and is carried by two bearings in the upper frame *D*. The clay is divided and directed downwards by the curved arm *E*, which revolves with the screw shaft, while the lower part of the screw forces the clay into the pressing-chamber *B* and into the brick mould *F*, which is a parallel block, equal in thickness to a brick, and sliding between fixed plates above and below. There are two moulds *F* and *G*. The mould-block *F* slides backwards and forwards by means of the revolving cam *H*, which acts on two rollers in the frame *I*, and is connected with the mould-block by a rod sliding through fixed eyes.

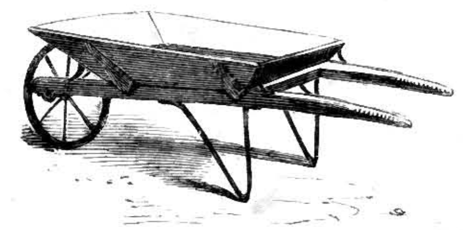

148. WASH MILL.


149. PUG MILL.

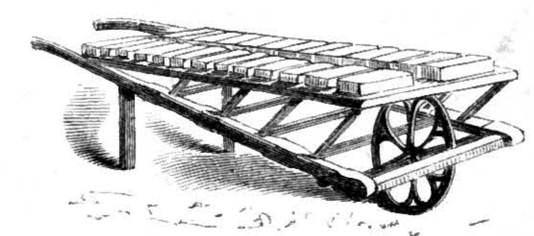

150. KICK AND STOCKBOARD.

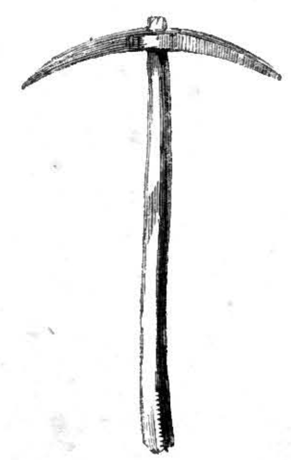

151. STRIKE.

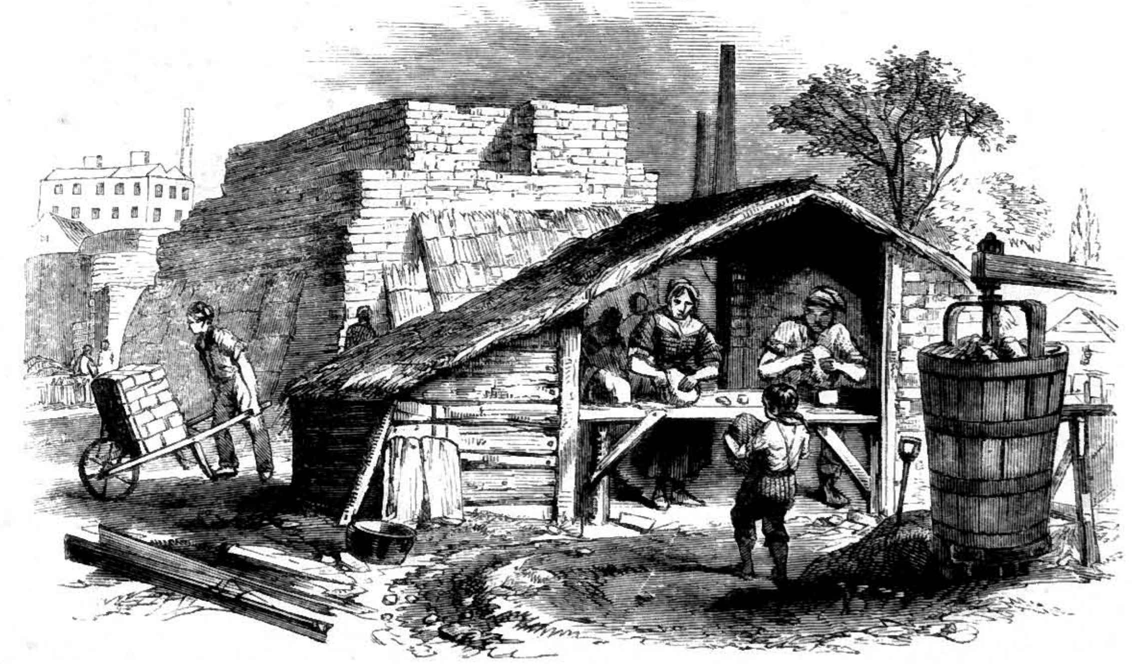

152. MOULD.

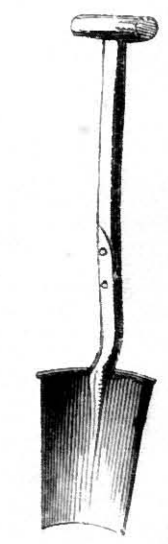

153. BARROW.

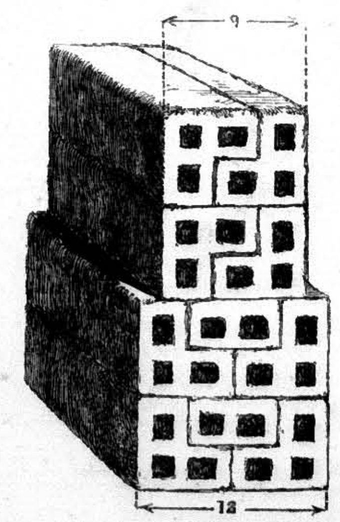

154. PALLET.


155. HACK BARROW.

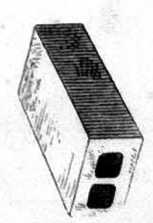

156. PICK.

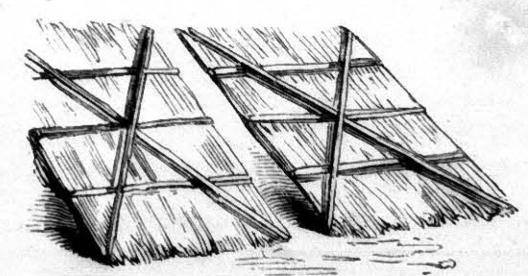

157. BRICKFIELD, MOULDER'S BENCH, KILN, &c.

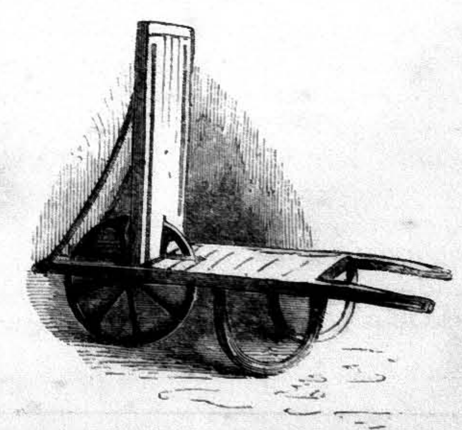

158. SHOVEL.



159. METHOD OF LAYING HOLLOW BRICKS.


160. HOLLOW BRICK.


161. REED FLATS.

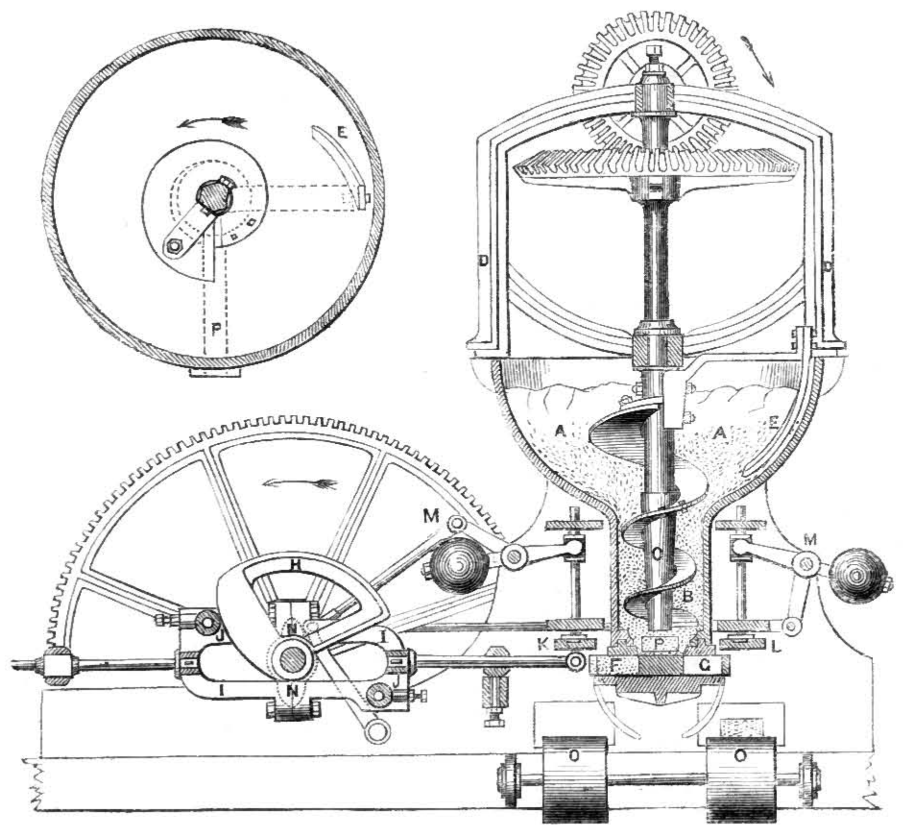

162. BARROW FOR CARRYING BAKED BRICKS.

In this way the two brick-moulds are placed alternately under the opening of the pressing-chamber *B*, for receiving a charge of clay, the block remaining stationary in each position during one quarter of a revolution of the cam *H*. When the brick-mould *F* comes out of the pressing-chamber, it is met by the piston *K*, which descends and forces the brick out of the mould. This piston is pressed down by the lever *M*, worked by the cam *N*, and at the end of the stroke of this piston the brick-mould is drawn up. A second piston *L* acts in like manner on the brick-mould *G*. The bricks, as they are turned out of the mould, are received by endless bands *OO*, which convey them to the front of the machine, where they are removed by boys to the kilns.

At *P*, seen also in the section of the screw, is an escape pipe of the same form as the brick-mould, but extending horizontally from the side of the pressing-chamber, and it is open at the outer end. Its object is to prevent too much pressure taking place in the cylinder, and it also assists in keeping up a uniform pressure. The regular action of the screw forces clay into this pipe, and the resistance produced by its friction in sliding through the pipe is the measure of the amount of pressure in the machine. The escape pipe discharges a continuous bar of solid clay, which advances by steps of a quarter to half an inch in length, each time the brick-mould is shut off and changed.

The upper side of the solid block that separates the two moulds, *F* and *G*, is faced with steel, and the upper face of the brick is smoothed by being sheared off by the edge of the opening of the pressing chamber, while the under face of the brick is smoothed by a steel bar fixed along the under edge of the plate.

The screw-shaft is driven by bevil-gear, the speed depending on the quality of the clay, or the wear of the screw. When at full speed, the screw makes about thirty revolutions per minute, or one brick for every turn of the screw. The machine makes as many as 12,000 bricks in a day. It usually makes about twenty-four bricks per minute, but it has produced as many as 200,000 bricks in a fortnight of eleven days. The clay, within a quarter of an hour after being brought from the pit, may be seen stacked in kilns, and, in a few days, burnt ready for use. Such bricks are said to be much stronger than ordinary hand-made bricks.



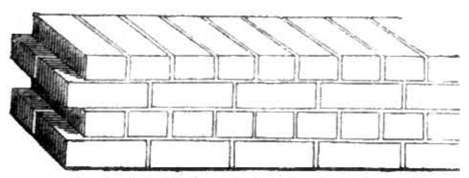
OATES'S BRICK-MAKING MACHINE.
(*Longitudinal Section.*)
The detached circular figure shows the plan of the screw.

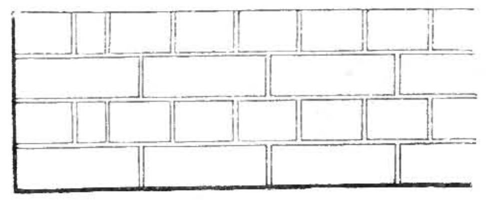
VIII.—THE BRICKLAYER.

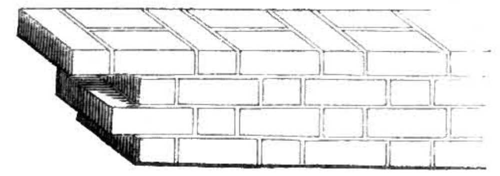
The bricklayer was never more active than at the present time. The vast increase of houses in the neighbourhood of London is a convincing proof of the prosperous state of his trade. In the country, also, similar signs of activity are in many directions to be observed, and we can only hope that the mania for cheap and rapid building may not be indulged, to the cost of the owners and occupiers of such houses. Bricklaying of the best and of the worst description may be seen in London; houses of careful and solid construction, raised on secure and good foundations, and houses hastily built of bad materials, on no foundation at all. From the very nature of brick walls, it is obvious that a safe and secure foundation is of importance. Trenches should be dug, and the ground carefully examined, to ascertain its soundness. The looser parts of the soil should be dug up until the solid bed is reached, and the ground should be made good by ramming in large stones closely packed together, or by the use of concrete.

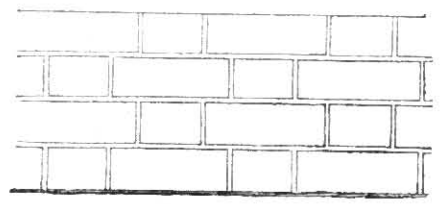
Ordinary English bricks are usually of one form, nine inches long, four and a half inches broad, and two and a half inches deep. Their quality depends on the materials of which they are made, the method in which the clay is tempered, and the manner of burning. The lime used for mortar is slacked in small quantities, and covered with finely sifted sand to exclude the air (fig. 174). When used, it is beaten three or four times, and turned over with a beater, so as to incorporate the lime and sand, and a little more water is then added. In hot and dry weather the mortar is made much softer than in winter: the bricks also are wetted before they are laid, otherwise in dry seasons they fail to adhere to the mortar. The building of a wall must be gradual, for the work will always shrink, and time must be allowed for it to do so equally. Four or five feet at any one part is as much as is usually built at one time. The strength of the wall (supposing the foundation to be good) depends on the manner in which the bricks are laid. There are two methods, in one or the other of which nearly all English brickwork is executed. The first is called *Old English bond*, and the bricks are laid in the manner shown in fig. 163. The first layer is formed with bricks laid lengthwise, and this forms what is called a *stretching-course*, and the separate bricks are called *stretchers;* the second course is formed with bricks laid crosswise, and this is called a *heading-course*, and the separate bricks *headers*. Flemish bond was introduced into England about the reign of William and Mary, and is formed by placing stretchers and headers alternately in the same course (fig. 165). This is thought to produce a more pleasing effect externally, but does not form so strong a wall. The perpendicular face of a wall built in Old English bond, and another built in Flemish bond, are shown in figs. 164, 166. In English bond it is a fundamental rule, that every brick in the same course must be laid in the same direction, but that no brick shall be placed with its whole length alongside of another; but be so situated, that the end of one may reach to the middle of the others which lie contiguous to it, except at the end of the course, where, to prevent a continued upright joint in the face-work, three-quarter bricks are necessarily used. This rule shows at once a source of superiority over Flemish bond, where it is impossible to adopt it, and where the walls are consequently weaker. In fact, the frequent splitting of walls done in Flemish bond has led to the practice of putting laths, or slips of hoop iron, in the horizontal joints between the courses. A careful adjustment of bricks is required in turning the corners of a wall, as that is the part where a house is most liable to split. If you call in your landlord, and inform him that you have noticed signs of weakness in your house, that you feel the vibration of passing vehicles too acutely, and that you hear sundry cracking sounds in various parts of the building in dry weather, he immediately walks to the corners of the room and examines their condition. If the papering or the paint be not defaced, if no crack or appearance of giving way is there visible, and if all the rooms of the house are in a similar condition, he assures you that you may feel perfectly secure. Knowing as he does that the foundation is good, he is very well aware that no serious mischief can happen to the house, without some such signs of weakness at the corners of the building. The corners of a wall laid in English bond are much after the manner shown in figs. 167, 168. Fig. 168 represents a two-brick wall, where every alternate header in the heading-course is only half a brick thick on both sides; which breaks the joints in the core of the wall, and where the arrangement for securing strength to the corner is also shown. Fig. 167 represents the mode of working English bond in a fourteen inch or brick and a half wall, in which the stretching-course upon one side is laid, so that the middle of the breadth of the bricks on the opposite side falls alternately upon the middle of the stretchers and upon the joints between the stretchers. It is usual to let the bricks of a wall incline slightly towards the centre, that one-half of the wall may be in a measure a support to the other half. Unfinished walls must be carefully preserved by means of straw and wooden coping from the effects of rain and frost. Were rain to penetrate the wall, and frost to convert the water into ice, the expansion in freezing would burst the wall, and crumble the materials of which it is composed. After a wall is built, the joints of the bricks on the outside are often filled up with mortar, so as to present a regular and neat appearance. In order to do this effectually, the mortar already in the joints is raked out to a certain depth, and filled up again with blue mortar. This filling up is called *pointing;* if the courses are simply marked with the edge of the trowel, it is called *flat-joint pointing;* if, in addition to this, plaster be inserted in the joints, and neatly pared and finished, it is called *tuck-pointing* or *tuck-joint pointing*.

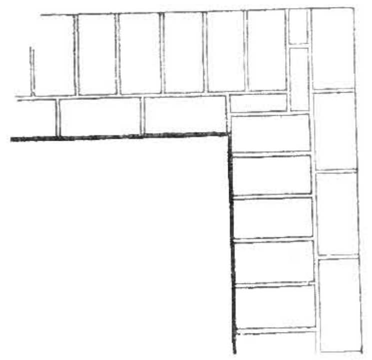
In all these works, the bricklayer needs but few and simple tools. In the first place, he must have a *brick-trowel*, of which two shapes are shown in figs. 169, 170. These are for taking up and spreading the mortar, and pressing it into crevices, and also for cutting bricks by percussion to any required size. Holding a brick in one hand, and giving it a smart blow or two with the edge of the trowel, the workman easily divides the brittle material at the desired part, while he also makes that ringing sound which proclaims all over the neighbourhood that building is going on. Next, he must have a *hammer* (fig. 171), one end of which does similar service in dividing bricks and making holes in brick-work, being for that purpose shaped like an axe. The *plumb-rule* (fig. 176) is necessary to enable him to carry up his walls perpendicularly: it is a thin rule, six or seven inches wide, with a line and plummet hanging in the middle; while this enables him to keep the perpendicular, the *level*, with its line and pins (fig. 179), assists him in preserving the horizontal level. He may often be seen trying with this instrument (which is ten or twelve feet long, and has a vertical rule attached to it, in which the line and plummet swing) the levels of the walls at various stages of the building, especially at the window-sills and wall-plates. He will also need a *square* (fig. 172), for setting out the sides of a building at right angles; a *jointer* (fig. 173), which is used with a rule for marking the joints, and is an iron tool shaped like the letter S; and a *raker* (fig. 175), a piece of iron with sharp points, for raking out mortar from the joints of a house when it is to be pointed. Another implement, characteristic of a bricklayer, is a *hod* (fig. 181). This is a wooden trough, closed at one end and open at the other: the sides of this trough consist of two boards at right angles to each other, having a long handle fixed to the middle of the ridge. On this ridge is also a cushion of leather, stuffed with wool, to prevent it from cutting the labourer's shoulder, as he rests it there in conveying it, laden with bricks or mortar, to the spot where the bricklayer is at work. The hod is duly sanded, to prevent the mortar from sticking to it; and it is often so heavily laden, that the task of carrying it up ladders, or across portions of the building or scaffold-

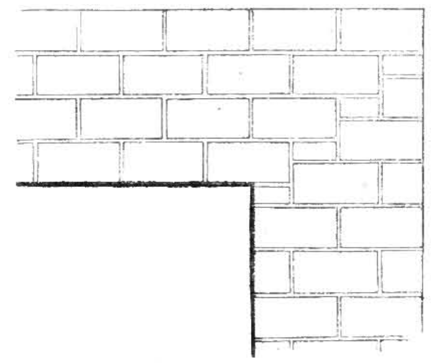

163. ENGLISH BOND.

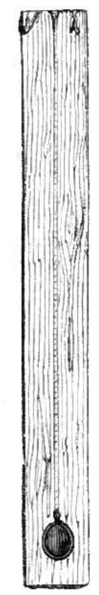

164. ENGLISH BOND. (*Elevation.*)

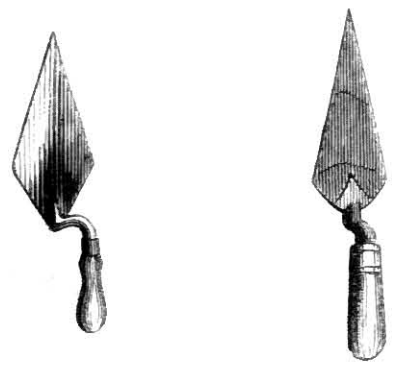

165. FLEMISH BOND. (*Elevation.*)

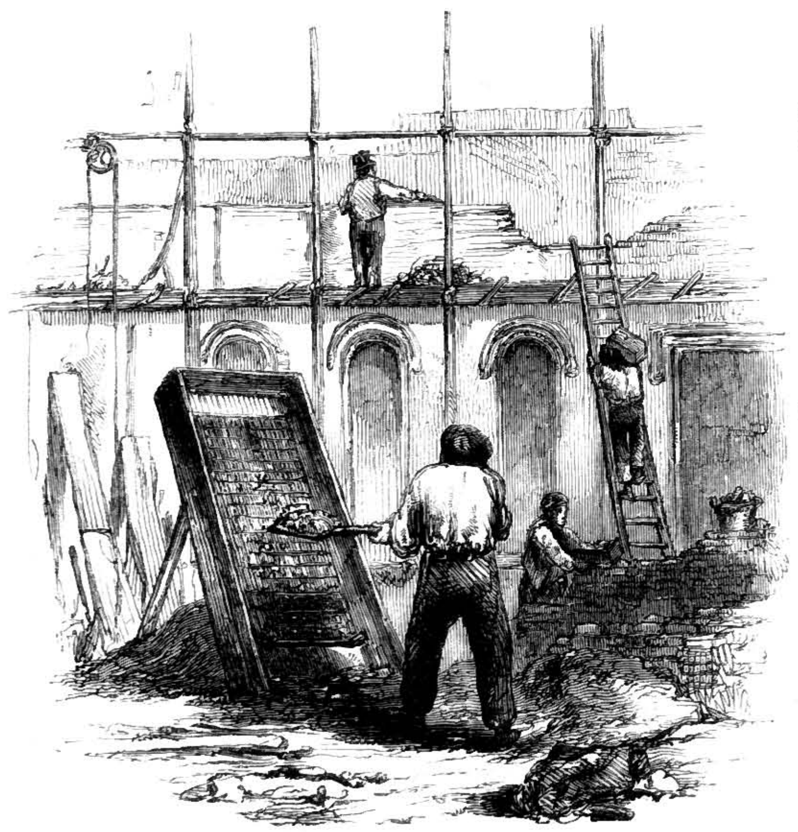

166. FLEMISH BOND. (*Elevation.*)

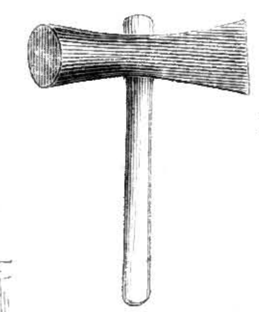

167. BRICK AND A HALF WALL. (*Plan.*)

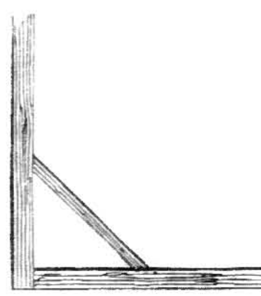

168. TWO-BRICK WALL. (*Plan.*)


176. LINE AND PLUMB.

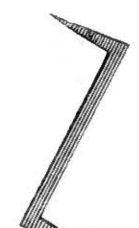

169, 170. TROWELS.


174. SCREENING SAND AND BRICKLAYING.

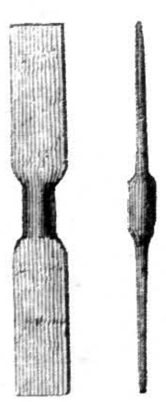

171. BRICK HAMMER.

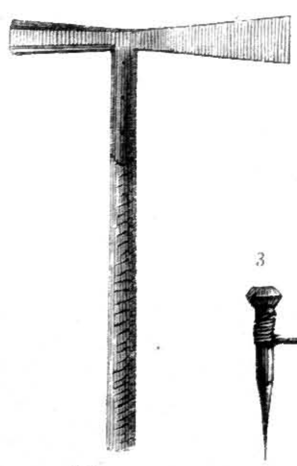

172. SQUARE.

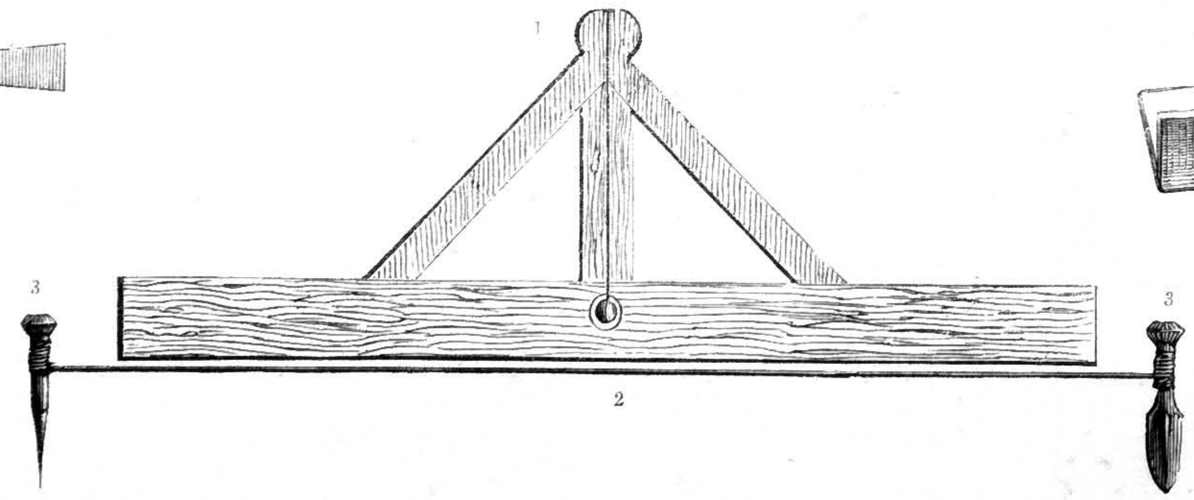

173, JOINTER.


175. RAKER.

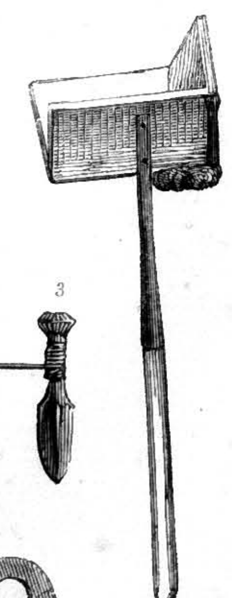

180. SHOVEL.


177. CUTTING CHISEL.


178. BRICK HAMMER.



179. 1. LEVEL. 2. LINE. 3. PINS.


181. HOD.


182. CROWBAR.


183. MORTAR RAKE.

ing where the footing is precarious, is no easy matter. For the preparation and cutting of gauged arches of brickwork, the *brick-axe*, or *cutting-chisel* (fig. 177), is employed for axing off the soffits of bricks. For the coarser works connected with the foundation, and with the preparation of materials, the *pickaxe*, the *shovel* (fig. 180), the *crowbar* (fig. 182), and the *mortar-rake* (fig. 183), are all necessary. The cutting of bricks for nice or ornamental work requires a *bench* and a *cutting-block*, and several additional tools, such as the *camber-slip*, a long slip of wood with a curved edge, rising about one inch in six feet; a *rubbing-stone* fixed to the bench, for rubbing down bricks which have been roughly shaped for gauged work; the *bedding-stone*, a piece of marble for trying the rubbed side of a brick, to ascertain that it is straight; a *bevel*, for drawing the soffit line on the face of the bricks; the *mould*, for forming the face and back of the brick, in order to reduce it in thickness to its proper taper; the *scribe*, a spike or nail, to mark the bricks; a *tin saw*, for cutting soffit lines one-eighth of an inch deep; the *templet*, used for taking the length of the stretcher and width of the header; and the *float-stone*, for rubbing curved work smooth, and to take out the marks of the axe.

Brickwork is estimated by its measurement in *rods*. A rod of brickwork consists of 272 superficial feet. The standard thickness of a brick wall is one brick and a half, or 13½ inches; so that, if 272 square feet be measured by 13½ inches, the result will be 306 cubic feet in the rod. A rod of standard brickwork with mortar will require about 4,500 bricks, allowing for waste. The mortar contained in a rod of brickwork consumes 1½ cwt. of chalk lime, or 1 cwt. of stone lime, and 2½ loads of sand with stone lime, or 2 loads with chalk lime. The weight of a rod of brick, containing 4,500 stock bricks, 27 bushels of chalk lime, and 3 single loads of drift sand, is about 13 tons. In common walling, where there are few or no interruptions in the way of recesses, &c., one bricklayer will lay 1,000 bricks each day, or complete a rod in about four days and a half. One labourer is assigned to each bricklayer, when the work is easily reached; but when the building has risen to some height and time is lost in mounting ladders, &c., a second becomes necessary. The labourer is paid at the rate of two-thirds of the bricklayer's wages per day.

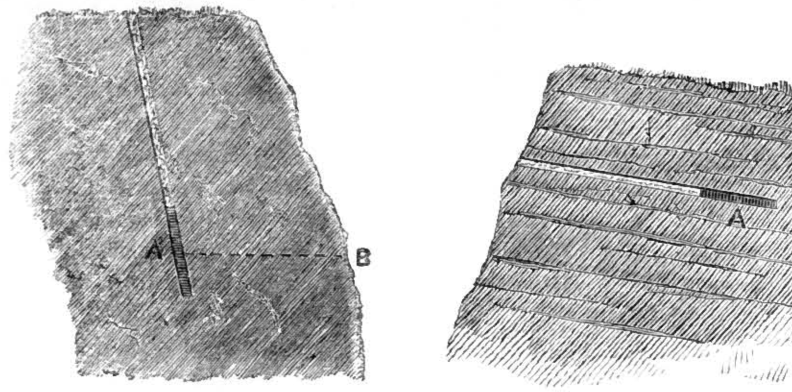
Under ordinary precautions, bricklaying need not be an injurious or a dangerous trade; yet we seldom hear of the erection of any extensive structure without some casualty to the workpeople employed. The fact is, that from long habit, they grow insensible to danger, and do not exercise the common caution which any man in his senses might be supposed to use under the circumstances. Great blame also rests on those who have the management of scaffolding, if they neglect to make it strong enough for the weight it will have to sustain, and for the number of workpeople required on the structure.

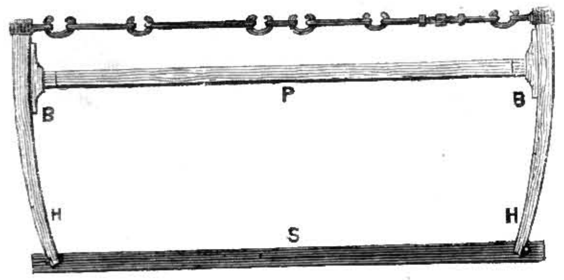
IX.—THE MASON.

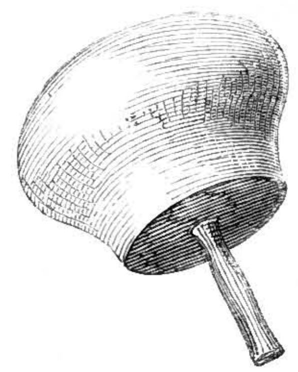
The various stones used in building are got out of the earth or separated from the rocks by the quarryman. The excavation from which the stone is got out is called a *quarry*, from the circumstance that the stones are squared or quadrated (*quarré*), or formed into rectangular blocks. In order to separate a block of stone from the rock, the quarryman bores a hole by means of a *borer*, or *jumping tool*, which consists of a heavy iron rod, something like a crowbar, which is lifted up and allowed to fall by its own weight, or it may be struck by means of a hammer, the jumper being turned after each stroke, so as to have a fresh portion of rock presented to its chisel edge after every blow. In this way a hole is formed, and every now and then the jumper is taken out, and the hole is cleared of chips by means of a scraper. When the hole is sufficiently deep, a quantity of gunpowder is poured into it; a long needle is then inserted into the hole and partly into the gunpowder, after which a little wadding of hay is put in over the powder, and the hole is filled up with broken brick or pounded stone, called *tamping*, which is rammed in by means of an iron rod, or tamping bar. The last inch or two of the hole is filled up with damp clay. The needle is then carefully pulled out, and the narrow opening left by it is filled up with gunpowder, or with straws filled with gunpowder, and into the upper end of the top straw is inserted a piece of touchpaper, sufficient to burn for half a minute: this is lighted; the men retire to a distance, the touchpaper fires the train, and the charge and the explosion loosen or detach a large mass of rock. The touchpaper is made by soaking coarse paper in a strong solution of saltpetre and drying it; but it is better to fire the charge by means of a *fuse*, which consists of a quantity of gunpowder enclosed within a hempen cord, and which burns or smoulders slowly. Fig. 184 shows the hole filled with this charge of gunpowder and tamping. When the charge is fired, it will break off a portion of the rock in the direction of the line *A B*. In stratified rocks, the hole is usually bored in the direction of the joints or seams, as in fig. 185, where the powder at *A* may be introduced in the form of a cartridge, and this will have more effect in lifting large masses than if placed across the grain. Gun cotton is now taking the place of gunpowder in blasting, as being more powerful and manageable. An explosive oily-looking liquid, known as *nitro-glycerine* or *glonoin* is also used in mining or quarrying operations. A single drop of this liquid struck with a hammer on an anvil produces a deafening report. It also explodes by being heated.

When the blocks are separated they are roughly brought to shape by means of the stone-axe (fig. 191), or the point (fig. 202).

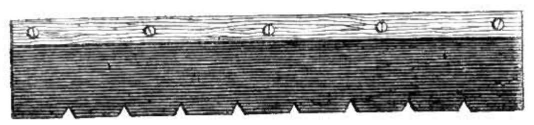
The tools employed by the mason vary in different places, according to the quality of the stone. In London, where stone is scarce, it is cut into scantlings by means of a saw (fig. 186). The saw *S* is from five to ten feet in length, and from one-sixth to one-eighth of an inch in thickness; it is fastened to the upright side of a frame *H*, at each end by an iron pin, and is kept distended by a wooden stretcher *P*, called the *pole*, placed near the top of the frame, while the upper ends of the frame are drawn together by means of a chain, to which tension is given by a double screw. The lower end of the frame serves as a handle, by which the saw is made to work forwards and backwards. The stone-cutter is represented at work in fig. 195: at the top of the block is a small barrel of water, resting on an inclined plane; the latter is covered with a sharp cutting sand, which trickles down with the water into the cut, and greatly assists in cutting the stone. The workman has near him a long stick furnished with an iron hook, called the *drip-stick*, with which from time to time he brings the sand into the path of the water. The saw-frame, which is very heavy, is usually counterpoised by means of a weight attached to a cord, and passing over a pulley so as to reduce the pressure, and lighten the load. The tall pole, seen in fig. 195, carries this weight. In this way a block of stone is with much labour cut up into a number of slabs. Sawing machines have been introduced, in which a frame containing eight or ten saws, moved by machinery, cuts up a block of stone in a comparatively short time. The slabs thus formed sometimes require to be cut into smaller slabs. When this is done by hand, a *grub-saw* (fig. 189) is used. This is a plate of iron clamped at the upper edge between two pieces of wood, to serve as a handle, and the cut is made with the assistance of water and sand, as before.

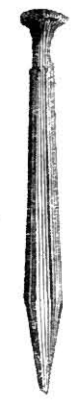

184, 185. METHOD OF BLASTING ROCKS.

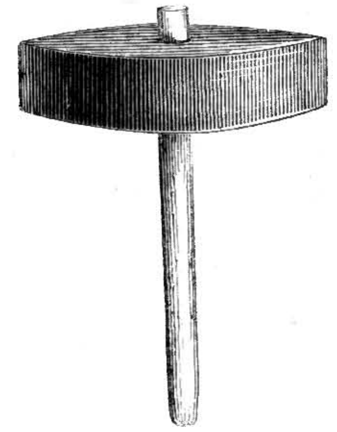

186. MASON'S SAW.


187. MALLET.

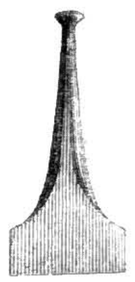

188. WASHING BRUSH.


189. HAND OR GRUB SAW.

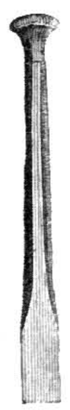

190. POINT.

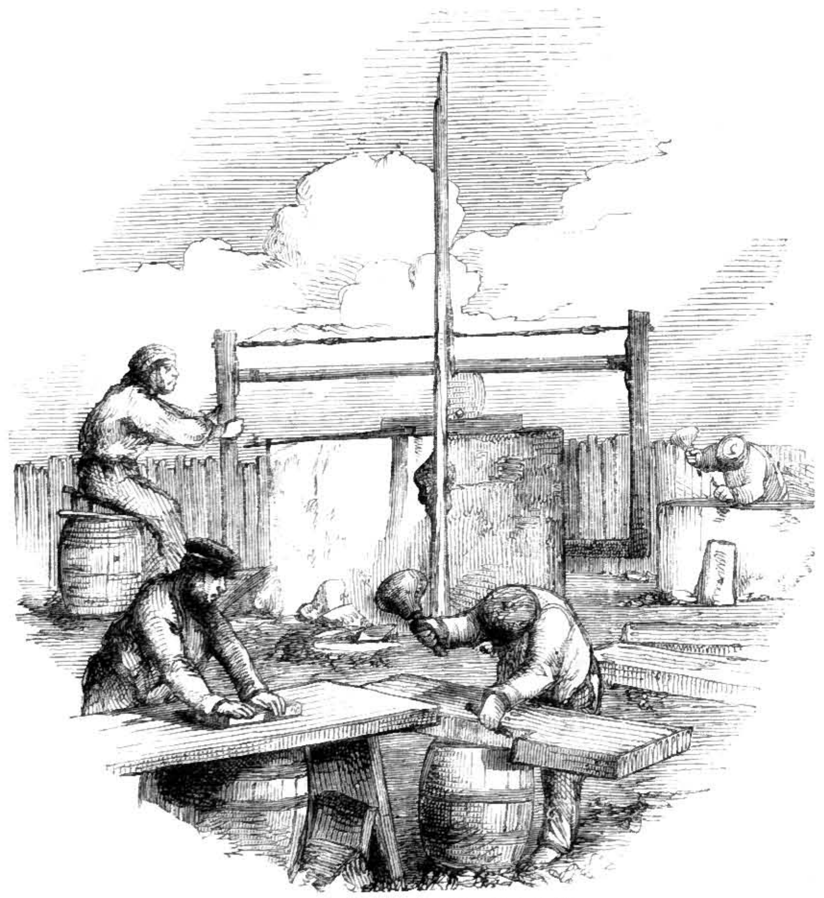

191. STONE AXE.

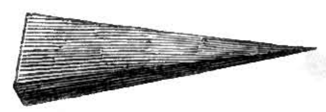

198* RUBBER.

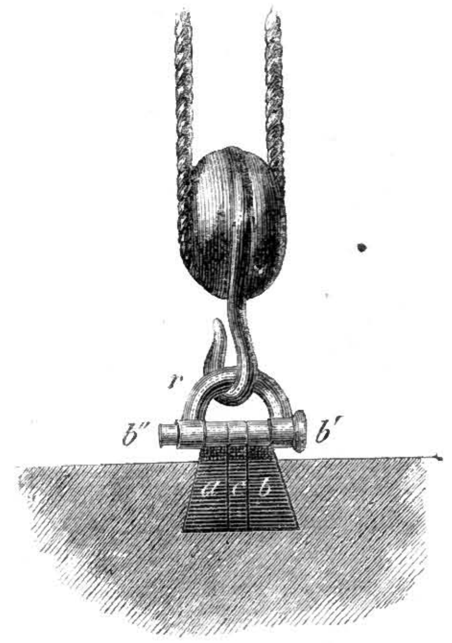

192. CHISEL.

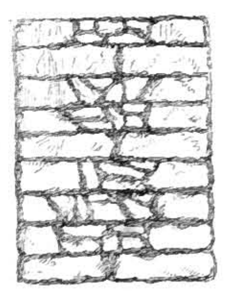

194. STRAIGHT EDGE.

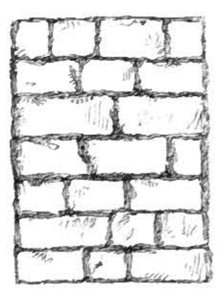

193. CHISEL.

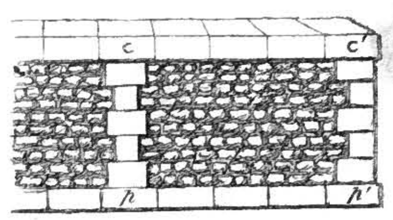

195. MASONS AT WORK.

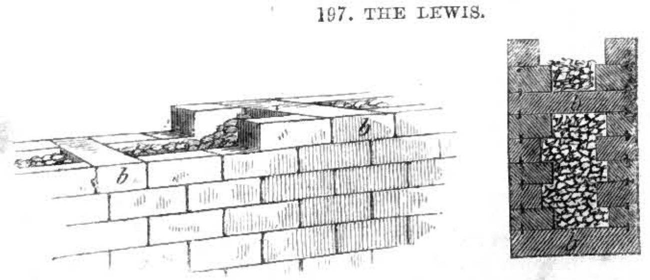

196. WEDGE.


197. THE LEWIS.

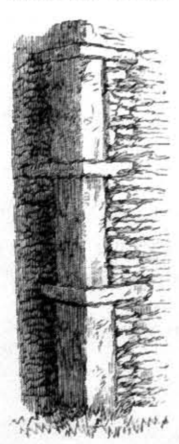

198. RUBBLE WORK.

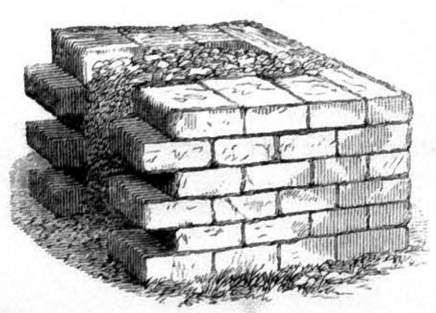

199. COURSED WORK.

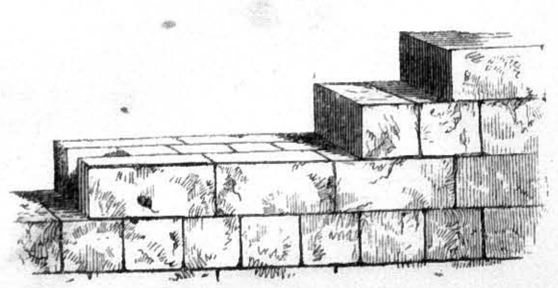

200. SUPERIOR RUBBLE.


201. WALL WITH HEADING OR BOND STONES.


202 PECK OR POINT.


203 LONG AND SHORT WORK


204. ROMAN EMPLECTUM.


205. ITALIAN.

This operation is also performed by machinery in what is called a *ripping-bed*, in which a number of circular saws, mounted on the same axis, perform the work very quickly. Slabs are smoothed by means of rubbers attached to the long rod (fig. 198*), consisting of coarse cloth, which are moved backwards and forwards over the slab by hand, the polishing material being sand of various degrees of fineness, and afterwards emery and putty-powder for finishing. The polishing of marble, &c., is also performed by machinery in what is called a *polishing bed*.

In places where stone is abundant, it is divided into smaller scantlings by means of wedges (fig. 196). Hard stone and marble are brought to a surface by means of a *mallet* (fig. 187) and *chisel* (figs. 192, 193). The tools used in London for hewing stones are of iron tipped with steel, and the cutting edge is the vertical angle. The mason also uses a *level*, a *plumb rule*, a *square*, a *bevel-square*, a *straight edge* (fig. 194), and various other *rules* for trying surfaces as the work proceeds. In working the face of a stone, the tools are the *point* (fig. 190), the *inch tool*, the *boaster*, and the *broad tool*. The operation of working with a point is called *pointing*, and that with the boaster, *boasting*. The action of the point is to leave the surface in narrow furrows, with rough ridges between them. The inch tool is used in cutting away the ridges, and the boaster in making the surface nearly smooth. The boaster is about two inches wide, and the broad tool $3\frac{1}{2}$ inches at the cutting edge. In working with the broad tool a series of cavities are produced following one another in a straight line, and the whole surface of the stone is gone over in the same manner, producing a number of equidistant parallel lines. This method of hewing is called *stroaking*. In another operation, which is called *tooling*, every successive cavity is repeated in new equidistant lines over the length or breadth of the stone, when a new series of cavities is repeated until the whole of the stone has been gone over. There are also various tools for working cylindrical and conical parts of mouldings.

In the erection of a stone building, the stones are placed in position by means of a contrivance called the *lewis* (fig. 197). This consists of three pieces of iron, *a c b*, with holes at the top for the insertion of a bolt *b′*, *b″*, and a ring *r*. A hole is cut in the middle of the upper surface of the stone about 7 inches in depth, and about 1 inch wider at the bottom than at the top. The pieces *a b* being first introduced into the hole, the piece *c* is driven in, the ring *r* is put in its place, and the bolt is passed through all five holes. It is evident that the instrument must hold the stone securely and allow it to be raised on a pulley, as shown in the figure. The lewis is said to have been invented by a French mechanic employed on the works of Louis XIV., and named in honour of that monarch. The examination, however, of ancient ruins shows that the lewis was known many centuries ago. In the year 1762 a portion of Whitby Abbey was blown down during a storm, when some of the stones, weighing nearly $1\frac{1}{2}$ ton each, were found to have a cavity in them similar to that which is now cut for the reception of the lewis. Whitby Abbey was rebuilt in the reign of William Rufus.

Various kinds of masonry are practised, and they may be ranged under three heads: *first*, *rubble-work* (fig. 198), in which the stones are used without being squared; *second*, *coursed work* (fig. 199), in which the stones are squared, more or less sorted into sizes and ranged into courses; *third*, *ashlar work*, in which each stone is squared and dressed to given dimensions. The thin facing of stone sometimes placed in front of brick work is also called ashlar. The rubble wall is often improved in appearance and solidity by the introduction of cut stone as in fig. 200, in which *c* is the *coping*, *p* the *plinth*, *δ p′* the *quoin*, and *c p* the *piers*. Sometimes the wall is cased on both sides with cut stone, the middle being filled with rubble, as in fig. 201, in which case *heading* or *bond* stones *b b* are carried at intervals through the thickness of the walls to prevent the sides from being forced apart by the interposed rubble.

When the top of a stone wall is horizontal the bedding-joints should be so too, but in bridge building and walls on inclined surfaces the bedding joints may follow the directions of the work. The footing of the stone walls should be made with stones as large as can be procured, squared and of equal thickness in the same course with the broadest bed downwards. The vertical joints in the upper courses must *break joint*, *i.e.* must not fall on those below. The header and stretcher system, as adopted by the bricklayer, may also be employed. Foundations should usually consist of several courses, decreasing in breadth as they rise, by *sets off* on each side of 3 or 4 inches, the number of courses being regulated by the weight of the wall, and by the size of the stones in these footings or foundations.

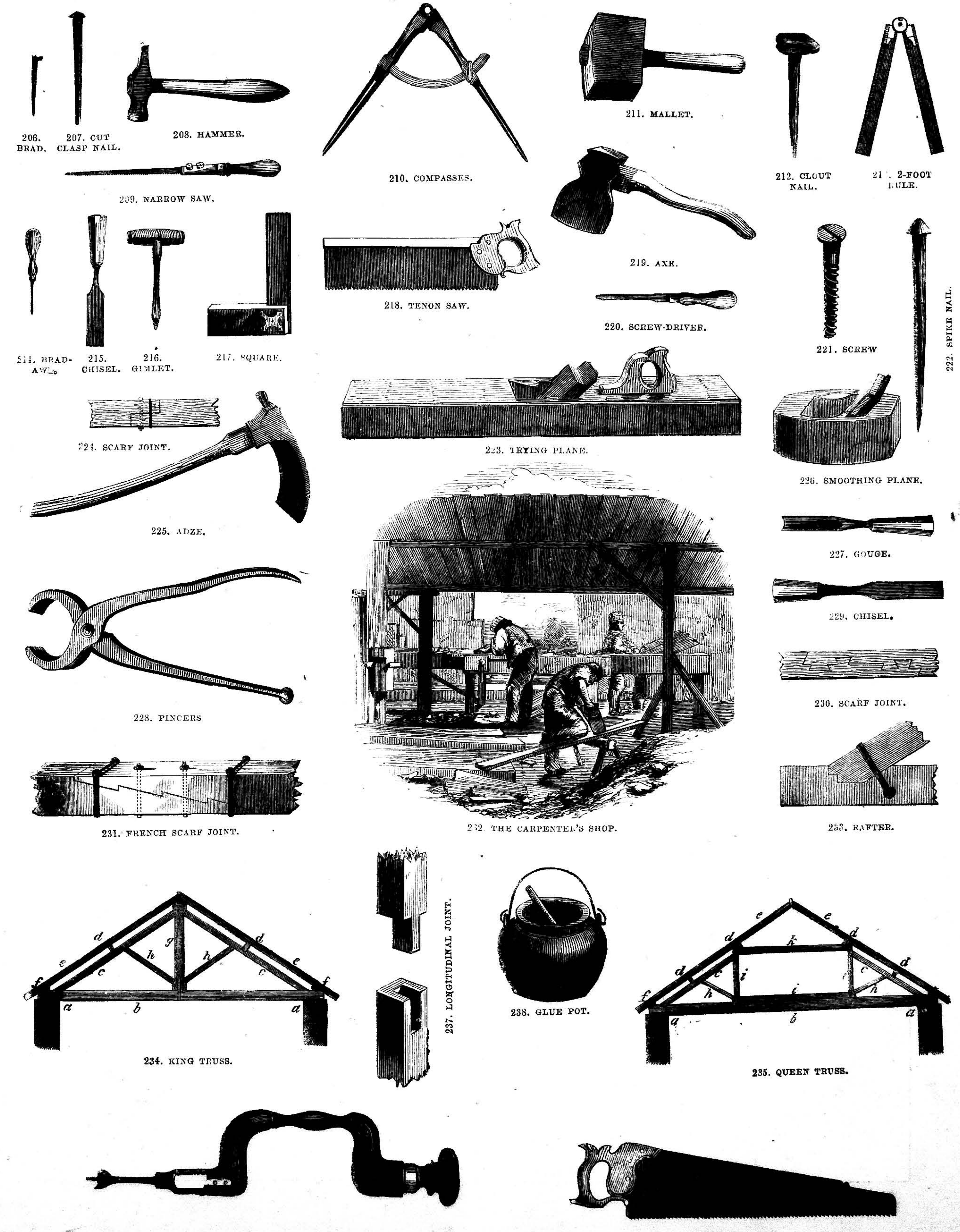
The walls built by the ancient Romans are still celebrated for their strength and solidity. The stones were usually laid in mortar, but where large blocks were used no cement was employed. Fig. 204 is a specimen of what is called *Roman emplectum*, in which the middle of the wall is of rubble. In some cases courses of tiles were built in at intervals, their large surfaces making a good bond. After the Romans had quitted Britain, various new forms of masonry were adopted, mostly inferior to the Roman. The quoins, the jambs of doors and windows, and some other parts were built of hewn stone in blocks alternately laid flat and set up on end, forming what is called *long and short* work (fig. 203). In the twelfth century the character of masonry improved; the mortar was finer, the stones were set with close fine joints, and ashlar was more generally used for the facing. Fig. 205 is a specimen of Italian masonry.

X.– THE CARPENTER AND JOINER.

It is the business of the carpenter to frame and put together roofs, partitions, floors, and other necessary parts of the building. The joiner begins his work where the carpenter leaves off, for it is his business to supply and fit up stairs, cupboards, furniture, and other parts required for convenience. We may illustrate some of the most important terms used in carpentry by means of two kinds of roof represented in figs. 234, 235. Pieces of timber laid on the wall in order to distribute the pressure of the roof equally, and to bind the walls together, are called *wall-plates*, or *raising-plates*, as at *a a*, while the horizontal piece of timber *b b*, connected to two opposite principal rafters, is called a *tie-beam*. It serves the purpose of preventing the walls from being pushed out by the thrust of the roof, and also of supporting the ceiling of the room below. When placed above the bottom of the rafters, it is called a *collar-beam*. The two pieces of timber in the sides of the truss which support a grated frame of timber over them for receiving the roof-covering or slating are called the *principal rafters*, as at *c c*. The horizontal pieces of timber *d d*, notched on the principal rafters on which, and on the pole-plates, the common rafters rest, are called *purlines*, while the pieces of timber *e e* placed at equal distances on the purlines, and parallel to the principal rafters, are called *common rafters;* their use is to support the boarding to which the slating is fixed. The pieces of timber *f f*, which rest on the ends of the tie-beams and support the lower ends of the common rafters, are called *pole-plates*. At *g* (fig. 234), is an upright piece of timber in the middle of a truss, framed at the upper end into the principal rafters, and at the lower end into the tie-beam; this is called a *king-post*, and its use is to prevent the tie-beam from sinking in the middle. *Queen-posts* (*i i*, fig. 235) are two upright pieces of timber framed below into the tie-beam, and above into the principal rafters; they are placed at equal distances from the middle of the truss or its ends. *Struts* or *braces*, *h h*, are oblique straining-pieces framed below into the queen-posts or king-posts, and above in the principal rafters, and supported by them. *Puncheons* or *studs* are short transverse pieces of timber fixed between two others for supporting them equally. A *straining beam* (*k*, fig. 235) is a piece of timber placed between the queen-posts at their upper end so as to withstand the thrust of the principal rafters; while a similar piece placed upon the tie-beam at the bottom of the two queen-posts for resisting the force of the braces which are acted on by the weight of the covering, is called a *training-cill*, middle *i*, fig. 235. There are other terms, such as *camber-beams*, or horizontal pieces of timber made sloping on the upper edge from the middle towards each end, for discharging the water. *Auxiliary rafters*, *principal braces*, or *cushion rafters*, are pieces of timber framed in the same vertical plane with the principal rafters under, and parallel to them, for giving additional support.

An important part of the business of the carpenter is that of *joints*. These may be used for lengthening timbers, or they may be *framing* and *bearing* joints, used in trusses, flooring, &c. or joints for ties and braces. Timbers may be connected lengthwise by bringing the two beams end to end, placing a short piece on each side, and bolting through these short pieces and the main beams; but this is not a neat method; it is therefore more common to apply the operation of *scarfing*, in which case one-half of the substance of each beam is cut away for a short length, and the cut portions being brought together are fastened by means of screws, straps, bolts, or wedges. Thus the common *scarf-joint* (fig. 224) is made by halving each piece of timber for a certain length, and bolting or strapping the two pieces together; but where it is an object to secure strength in resisting longitudinal strains, such a joint as that shown at fig. 230 is employed either with or without bolts. The French scarf-joint (fig. 231) is called, from its fancied resemblance to the form of a flash of lightning, *trait de Jupiter;* this figure also shows the method of applying bolts and straps. Fig. 237 shows a *longitudinal joint* which may be used where a vertical pressure only is to be borne. Fig. 233 shows a *framing-joint* used in the construction of a principal rafter. Such joints are made on the principle of a *tenon* and *mortise*, in which one of the pieces to be joined is cut away so as to leave a small projection or tenon, while a corresponding cavity or mortise is made in the other piece to receive the tenon.

There are many other particulars which might be given respecting floors and partitions, &c.; but enough has been said to show the nature of the house-carpenter's work. The various tools used by him are represented in the figures, not very accurately indeed, but they are all so well known, that the defects of the figures may be supplied by the experience of the reader. In carpenters' work the timber remains rough, as left by the saw; but in joiners', it is brought to a smooth surface by means of the plane, wherever it is exposed to view. The chief cutting tools used by the joiner consist of saws, planes, and chisels. There are various kinds of saws, distinguished by their shape and the size of the teeth: thus the *ripper* has 8 teeth in a length of 3 inches; the *half-ripper* 3 teeth to the inch, the *hand* saw (fig. 239) 15 teeth in 4 inches, and the *panel* saw 6 teeth to the inch. The *tenon* saw (fig. 218), which is used for cutting tenons, has about 8 teeth to the inch, and the blade is prevented from *buckling* or bending by means of a thick piece of iron at the back. The *sash* saw has a brass back, and 13 teeth to the inch, while the *dove-tail* saw has 15. The *key-hole* saw (fig. 209) is used for cutting out small holes. There are also various kinds of planes: those used for bringing the stuff to a plane surface are called *bench* planes, and of these the *jack* plane is used on the roughest work, while the *trying* plane (fig. 223) is used after the jack plane for *trying-up*, or taking off shavings of the whole length of the stuff. There is also the *long* plane, 2 feet 3 inches in length, the *jointer*, 2 feet 6 inches in length, and the *smoothing* plane, 7½ inches in length, used for cleaning off finished work. There are also various *moulding* planes for forming or *sticking* mouldings, as it is called. Chisels (figs. 215, 229) are also of various forms and uses, such as the *paring chisel*, which is used by the pressure of the hand only; the *socket chisel*, used with the *mallet* (fig. 211). The *gouge* (fig. 227) is only a curved chisel. The boring tools are the *brad-awl* (fig. 214), the *gimlet* (fig. 216), the *brace and bit* (fig. 236), the latter admitting into the handle or *stock* a variety of *steel bits* of different bores and shapes for boring and widening holes in wood and metal. The joiner also uses the *screw-driver* (fig. 220), the *pincers* (fig. 228), the *hammer* (fig. 208), the *axe* (fig. 219), and the *adze* (fig. 225). It may be remarked that the *glue-pot* (fig. 238) is not used by the house-carpenter or joiner, but belongs rather to the cabinet-maker.



206. BRAD. 207. CUT CLASP NAIL. 208. HAMMER. 209. NARROW SAW. 210. COMPASSES. 211. MALLET. 212. CLOUT NAIL. 213. 2-FOOT RULE. 214. BRAD-AWL. 215. CHISEL. 216. GIMLET. 217. SQUARE. 218. TENON SAW. 219. AXE. 220. SCREW-DRIVER. 221. SCREW. 222. SPIKE NAIL. 223. TRYING PLANE. 224. SCARF JOINT. 225. ADZE. 226. SMOOTHING PLANE. 227. GOUGE. 228. PINCERS. 229. CHISEL. 230. SCARF JOINT. 231. FRENCH SCARF JOINT. 232. THE CARPENTER'S SHOP. 233. RAFTER. 234. KING TRUSS. 235. QUEEN TRUSS. 236. BRACE AND BIT. 237. LONGITUDINAL JOINT. 238. GLUE POT. 239. HAND SAW.

XI.—THE SLATER AND THE PLUMBER.

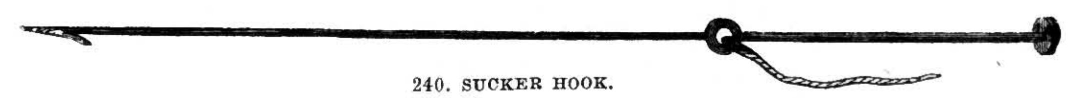
UNDER this head we may briefly refer to the various materials used for roof coverings, of which there are three classes; namely, stone, wood, and metal. Slates belong to the first kind: those from Wales, which are of a light blue colour, are considered the best. Slates from Westmoreland are of a dull greenish hue. They are of various sizes, and the Welsh slates are distinguished by odd names, such as *doubles*, 1 foot 1 inch by 6 inches; *ladies*, 1 foot 4 inches by 8 inches; *countesses*, 1 foot 8 inches by 10 inches; *duchesses*, 2 feet by 1 foot; *imperials*, 2 feet 6 inches by 2 feet; *rags*, and *queens*, 3 feet by 2 feet. The slater uses tools common to other trades, but there is one tool especially his own, called a *saixe*, *sax*, or *zax*. It is a kind of hatchet or chopper, with a sharp point at the back: with this he trims the slates and makes the holes by which they are fastened in their places. Slates are laid either on boarding, or on narrow battens, from 2 to 3 inches wide; the latter being the less expensive method. The slates are fastened by means of copper or zinc nails, and each slate should be secured with two nails. The upper surface of a slate is called its *back*, the under one the *bed*, the upper edge the *head*, and the lower edge the *tail*. The portion of each course which is exposed to view is called the *margin*, and the width of the margin, the *gauge*. The distance which the lower edge of one course overlaps the slates of the next lower course, measuring from the nail-hole, is called the *bond* or *lap*. The method of attaching the battens to the rafters and fastening the slates will be understood by referring to fig. 260. Sawn slate is also used for chimney-pieces, shelves, cisterns, baths, and ornamental purposes.

In places where laminated stone, or stone that can be easily split, is abundant, thin slabs are used for roofing, but this kind of covering is heavy, and requires strong timbers for its support. Tiles form another covering: when flat, they are called *plain* tiles, and when curved so as to lap over each other at the sides, *pan* tiles. Wooden coverings, such as *shingles* of split oak, are sometimes, but not often, used for coverings. Metallic coverings consist of thin sheet *copper* (but this is too expensive for general use); sheet *zinc*, which is both light and cheap; *iron*, coated with zinc, to protect it from rust, which has, of late years, come into use; but the most common material is *lead*, which has the advantages of being easily spread out and adjusted to different surfaces, of being durable, and of resisting the action of the weather. It is cast in sheets, of the weight of from 4 to 8 lbs. to the square foot, either by spreading it out in a molten state on a large table covered with sand, as in fig. 254, or by passing it through a rolling mill. In the latter case, it is called *milled lead*. In casting sheet lead, the metal is made fluid in a cast-iron *melting pot*, from which it is ladled into a trough, called the *pan*, the length of which is equal to the width of the casting table. The trough is then tilted up and the melted lead poured out, when a wooden strike is passed over the surface of the metal, so as to spread it evenly over the table, or the trough itself may have a narrow aperture along its bottom, and when filled with melted lead be moved along the table, the lead flowing out as it advances. The thickness of the sheet will depend on the size of the aperture and the quickness with which the trough is moved over the table.

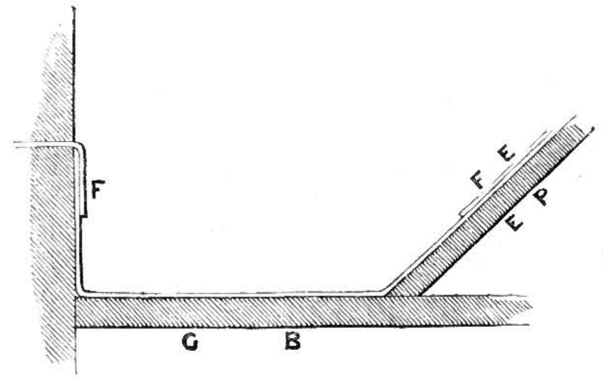
Metallic coverings are liable to great contraction and expansion by exposure to the weather. We have seen a copper roof covering puckered up in a most extraordinary manner by the heat of the sun. To prevent this, the joints should not be soldered or nailed, but should be *flashed*, that is, the edges should be turned down over the edge of another sheet, which is turned up against the wall, as at *F*, fig. 243, for which purpose the mortar is raked out of the joint of the bricks next above the edge of the sheet, and the flashings inserted into the crack at the upper side, while the lower edge is dressed over that of the lead in the flat or gutter. In fig. 243, *G B* is the gutter board, *E B* the eaves board, and *F E* the foot of the eaves course. As the sheets do not exceed 6 feet in breadth, water-tight joints are made by forming *laps* or *rolls*. A roll is a strip of wood, *R*, fig. 255, about 2 inches square, rounded on its upper side, over which one of the edges of the lead is dressed, and is covered by the edge of the adjoining sheet, and the whole being well hammered down, a water-tight joint is formed without any fastening. Lead flats and gutters should be made with a fall or *current*, as it is called, to keep them dry. The fall is usually from back to front, or in the direction of the length of the sheet. A quarter of an inch to the foot is a sufficient inclination, and the carpenter provides this while preparing the ground or platform for the lead.

Cisterns are usually made of wood or masonry on the outside, and are lined with sheet lead, the joints being secured by solder. Water trunks and pipes are fitted with large case-heads above, for receiving the water from gutter spouts, and with shoes below for delivering the water. They are attached to the walls by means of flanches of lead, and secured by spike nails. Service and waste pipes are attached by means of iron holdfasts.

The plumber requires but few tools. He is furnished with a *hammer* (fig. 245), wooden *mallets* of different sizes, and a *dressing* and *flatting* tool (fig. 242). This is of beech, about 18 inches long, and 2½ inches square, flat on the under surface, and rounded on the upper, with a handle at one end. This is for stretching out and flattening the lead, and dressing it to the required shape. The plumber also uses a *jack* and a *trying* plane for reducing the edges of sheet lead to a straight line. His cutting tools are *chisels*, *gouges*, and *knives* (figs. 247, 249) for cutting the sheet lead into slips and pieces, after marking it out with a chalk line. He also uses *files*, and when joints are required, the *soldering iron* (fig. 256), the joints being prepared by means of *shave-hooks* (figs. 251, 252). Solder is melted in a *ladle* (fig. 257), over a fire contained in the grate (fig. 258). The solder, called *soft solder*, is made of equal parts of lead and tin. The joints are smoothed down by means of *grozing* irons.


240. SUCKER HOOK.

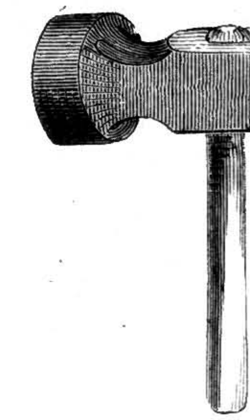

241. SCREWDRIVER.



243. LEAD COVERING FOR GUTTER.

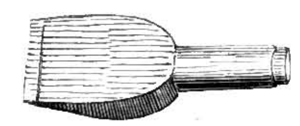

242. DRESSER, OR BAT.

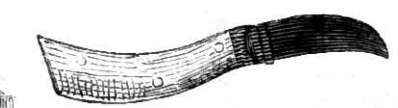

244. BOSSING MALLET.

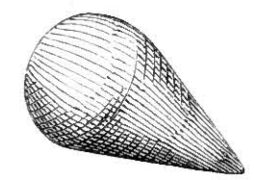

245. HAMMER.


246. DUNRING.


247. CHIPPING KNIFE.

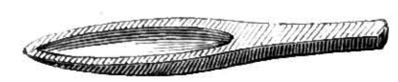

248. CHASED EDGE.

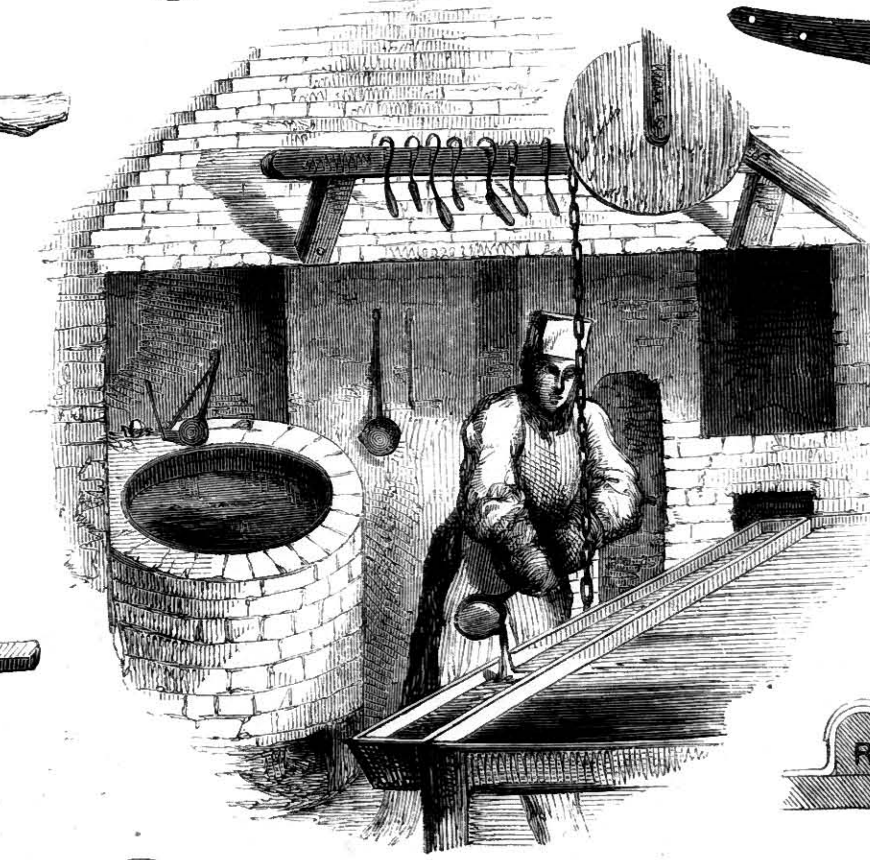

249. DRAWING KNIFE.

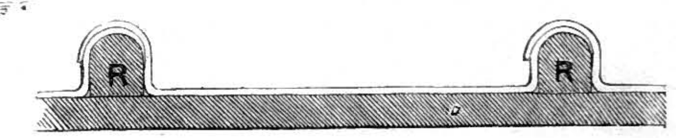

250. TURNPIN.


251. SHAVE HOOK.


252. SHAVE HOOK.

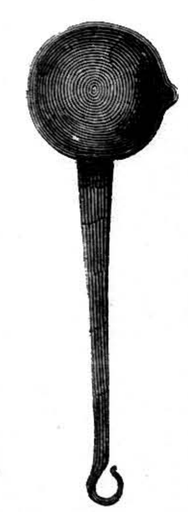

253. POURING STICK.


254. CASTING LEAD.



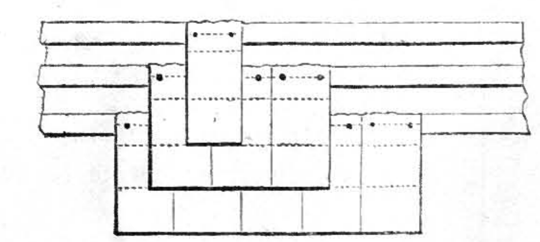
255. LAP OR ROLL.


256. SOLDERING IRON.


257. LADLE.


258. GRATE.


259. CHISEL.


260. SLATERS' WORK.

XII.—THE PLASTERER AND WHITEWASHER.

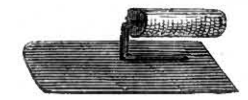
The business of the plasterer is to apply plaster or cements to walls, ceilings, &c., in order to conceal the roughness of the brick-work or masonry, or the timber framing of partitions, floors, roofs, and staircases, and also to allow the painter, paper-hanger, and house-decorator to begin their work. The plasterer has also to make and fix ornamental cornices, centre-pieces, &c. When a wall is to be plastered, the bricklayer leaves the joints rough and prominent so that the plaster may adhere; and in plastering old walls, some of the mortar is removed from the joints, and the surface of the brick-work made rough by *stabbing* and *picking* it over. In plastering upon partitions, or on the under surface of timber floors, *laths* are nailed to the timber quarterings or to the joists. Laths are usually of fir-wood about 1 inch in width, and from 3 to 5 feet in length; the thickness varies from a quarter-inch or *single lath*, to three-eighths or *lath and a half*; and half an inch or *double*; they are nailed across the joists with cast-iron nails. The first coat of plaster, called *coarse stuff*, is made with lime and sand mixed with ox or horse-hair, and is applied with a *trowel* (fig. 261), in such a way as to force the mortar into the narrow openings between the laths; behind which it hardens in small lumps, and thus becomes *keyed* firmly to the laths. When only two coats are applied, plastering is called *laid and set*: the first coat or the *laying* is levelled with the trowel, and when dry the surface is scratched up with a birch broom, and a thin coat or *set* of finer plaster is laid on and smoothed with a trowel. In applying one coat upon another, the surface is sprinkled with water by means of a bristle brush. In the better kind of work the first rough coat is scored over with a pointed lath, with cross lines 3 or 4 inches apart, to allow the second coat to adhere. The first coat may project a quarter or three-eighths of an inch from the laths, when it is called *pricking up*. When sufficiently dry, ledges of plaster six or eight inches wide, called *screeds*, are placed at the angles, and at intervals of a few feet across the surface to nearly the degree of projection or level of the finished surface, so as to serve as gauges for the rest of the work. The spaces or bays between the screeds are filled up flush with them, and the plaster levelled by means of flat wooden *floats* (fig. 275), made with one or two handles, those with two handles being called *Derbys* or *Derby floats*: *straight edges* (fig. 277), or long pieces of wood planed to a straight edge, are also used. When the second coat is dry it is swept over, and a third coat of *fine stuff* or plaster of fine white lime is carefully applied so as to form a smooth hard surface. When plaster is applied to a brick or stone wall, the first rough coat is called *rendering*. Fine surfaces such as ceilings, which are to be whitewashed or coloured, are finished with a fine plaster of the best powdered lime, well worked with water into a paste or *putty* as it is called. When surfaces are to be papered, a somewhat coarser stuff mixed with a little hair is used. Surfaces intended to be painted on are finished or set with bastard stucco formed of two-thirds ordinary fine stuff without hair and one-third fine clean sand: the last coat being finished with the trowel without the float.

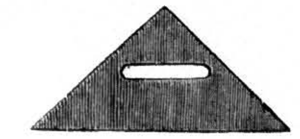
The plasterer has a labourer to supply his boards with mortar, and a boy to feed his *hawk* (fig. 269), which he does with the *salve* (fig. 278). The hawk is a piece of wood 10 inches square, held by a projecting handle at the bottom. The *laying-on trowel* (figs. 261, 263) is a thin plate of hardened iron or steel rounded at one end and square at the other, with a handle at the back. The *gauging trowel* (fig. 279) is used for gauging fine stuff for cornices, &c. The *drag* (fig. 280) is a two or three-pronged rake, used for mixing the hair with the mortar in preparing coarse stuff.

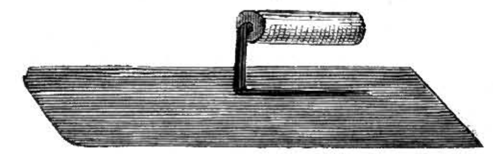
Cornices may be plain or ornamented. If they project more than 7 or 8 inches, *brackets* or pieces of wood are fixed 11 or 12 inches apart, and laths are nailed to them to support the plaster. A mould or profile of the intended cornice is made of beech-wood, with the *quirks* or small sinkings of brass. When a sufficient quantity of plaster has been laid on, the mould is held steadily and firmly to the ceiling and wall, and moved backwards and forwards, the effect of which is to shape the plaster to the form of the mould. Large cornices may require 3 or 4 moulds, and some parts may have to be modelled and filled up by hand with the assistance of the tools figs. 264, 267. Ornaments may be attached by means of plaster of Paris. The ornaments are cast in plaster of Paris from clay moulds, but of late years other materials have been introduced, such as *carver's compo*, consisting of a mixture of whiting, resin, and glue; *papier maché*, with a priming of whiting and glue over it for sharp impressions; *carton pierre*, with layers of whiting and glue; and *gutta percha*.

The plasterer makes use of a variety of compositions and cements. For the external coatings of buildings, *Roman cement*, *Portland cement*, and *lias cement* are used, while for delicate internal work, *Martin's* and *Keene's cement* are employed.

When the plasterer has completed his work, the whitewasher gives the whole a finished appearance by means of a lime wash, applied by means of a brush (fig. 265). In fig. 272, the plasterer and whitewasher are represented at work at the same time: this is a mistake, as it is necessary that the plasterer's work should be dry or nearly so before the whitewasher begins.

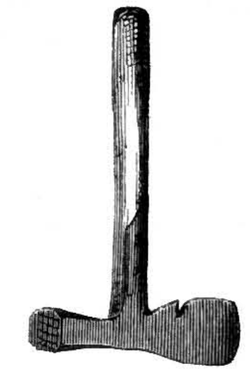

261. SETTING TROWEL.


262. SET SQUARE.

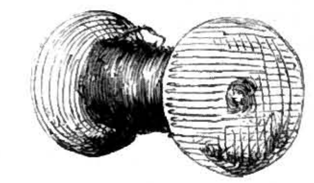

263. SETTING TROWEL.


264. MODELLING TOOL.

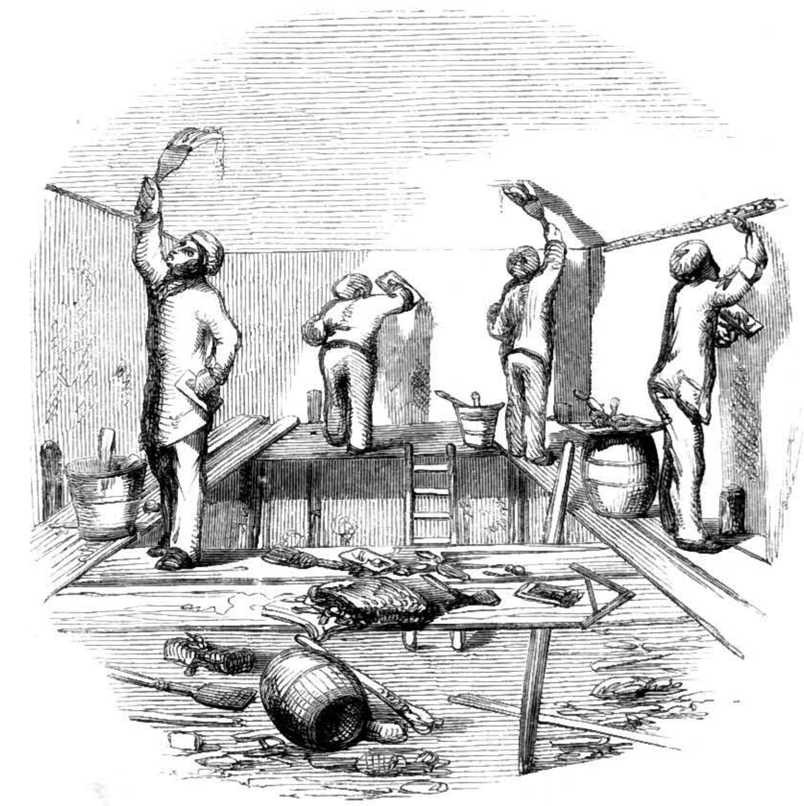

265. BRUSH.

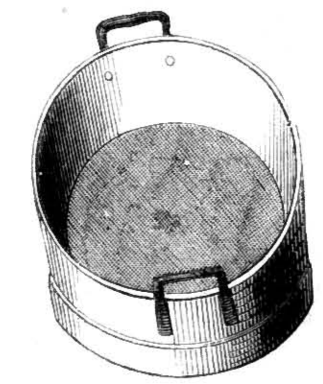

266. HAMMER.

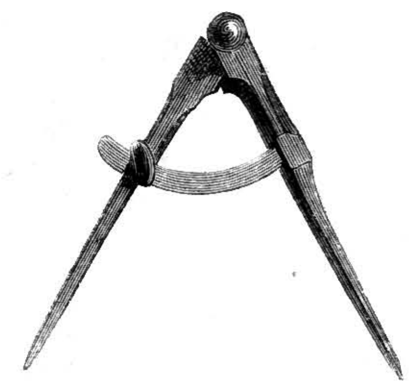

267. MODELLING TOOL.

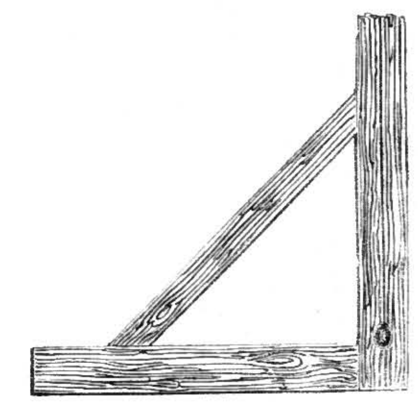

268. CHECK LINE AND REEL.

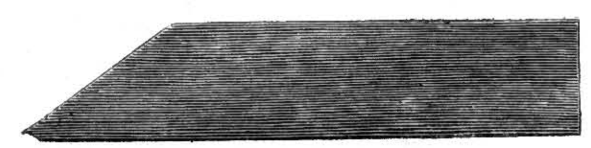

269. PLASTERER'S HAWK.

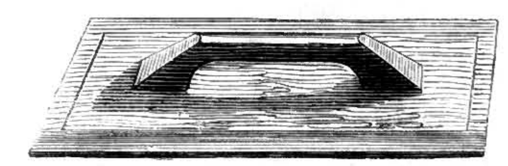

272. PLASTERER AND WHITEWASHER.


270. FINE SIEVE.


271. COMPASSES.


273. SQUARE.

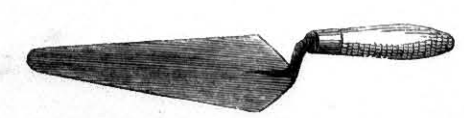



275. HAND FLOAT.


276. JOINT RULE.


277. FLOATING RULE.


278. SALVE.


279. GAUGING TROWEL.


280. HAIR HOOK.

XIII.—THE HOUSE-PAINTER AND GLAZIER.

THE work of the house-painter is to cover with a preparation of white lead and oil such parts of the joiner's, smith's, and plasterer's work as require to be protected from the action of the air. *Decorative painting* is a higher branch, and requires artistic skill. White lead is the basis of all ordinary paints, and forms at least nine-tenths of their composition. The paints may be ground on a stone or *slab*, with a *muller* (fig. 284), but the work is usually done on a large scale by the manufacturing chemist in paint mills, which resemble in some respects the mill used for grinding corn. White lead and linseed oil are chiefly employed, but other substances are used, such as colouring matters, or *stainers*, as they are called; also, drying materials, or *dryers*. The linseed oil is sometimes boiled, which assists the drying, but makes it thick, so that it is only fit for outdoor work. Spirits of turpentine, or *turps*, is much used. Litharge and sugar of lead, ground in oil, are employed as dryers, together with japanners' gold size. Among the pigments used as stainers are ochre, Venetian red, lamp-black, Indian red, Turkey and English umber, *terra de Sienna*, red lead, Prussian blue, orange red, chrome yellow, vermilion, &c.

The painter prepares surfaces for painting by rubbing them over with a flat face of pumice stone or with sand-paper, or by filling up the holes with putty. He punches in the heads of nails and stops them with putty. Knots in the wood, which would bulge out or leave a stain, are cut out, and pieces of wood glued in instead. In common work, the knots are painted over with red lead and size.

In painting plaster walls, four or five coats are required. The first consists of white lead made thin with linseed oil, and a little litharge is added to insure the drying. The plaster absorbs the oil and becomes hard on the surface. A thin second coat is added to saturate the plaster. The third coat is thicker, and contains some turps and a little of the colouring matter, while the fourth coat is quite thick. The colour is used several shades darker than the finishing coat, and the dryer is sugar of lead. Each coat is rubbed lightly over with sand-paper before the next one is applied. The finishing or *flatting coat* (as it is called, because it dries without gloss) is of pure white lead, diluted with spirits of turpentine only: it darkens in drying, and hence is used lighter than the pattern. A little japanners' gold size is used as the dryer.

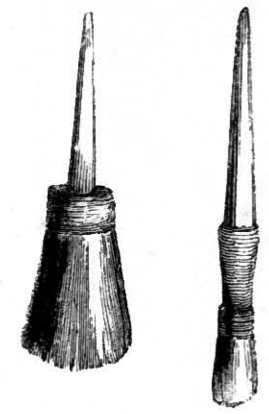
In painting wood, a similar course is to be adopted, each coat being thicker and smoother than the previous one. In imitations of oak, marble, &c. there is first a groundwork of four or five coats, and care is taken not to leave any marks of the brush. The last coat is not flatted, but consists of equal parts oil and turps; the shades and grain of the wood are given with thin glazings of Vandyke brown, *terra de Sienna*, or umber, &c.; these are ground in water, and mixed with small beer, which is slightly glutinous, and the whole is finished with a coat of varnish. Wainscot is painted thick, so that it may receive the impressions of an ivory or horn *comb* (fig. 299) by which the grain of the wood is imitated. A copal varnish is then applied. Imitations of marble, &c. belong rather to decorative painting.

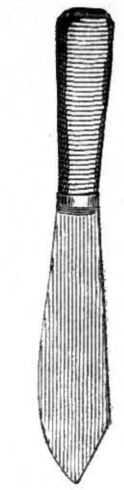
The painter works with *brushes* of hogs' bristles of different sizes (figs. 281, 282). The colours are contained in earthen *pots* (fig. 285), or in *kettles* (figs. 287, 298); the painter is also furnished with *cans* (fig. 293), for holding oil, a *palette knife* (fig. 286), for taking colour off the slab, and a *stopping knife* (fig. 283).

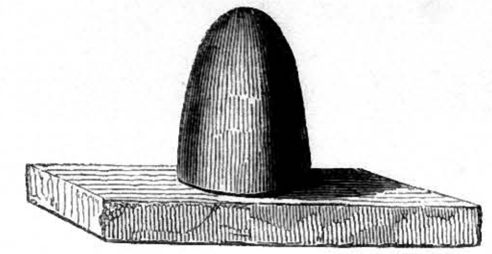
The work of the glazier is to cut out glass and fix it into leadwork or sashes. The sash-bars have a *rebate* outside for receiving the glass, which is *bedded* and *back-puttied* to secure it in its place. Putty is made of whiting and linseed oil, beaten together. Large squares of glass are also secured or *sprigged* with small brads driven into the sash-bars.

Lead-work is prepared by passing leaden rods, called *cames*, through a *glazier's vice*, which forms the grooves in which the glass is inserted. The bars are soldered together, so as to form squares or diamonds. The sides of the grooves are then turned down to receive the small panes, after which they are pressed firmly up against them.

The glazier cuts his glass by means of an unpolished *diamond*, fixed in lead, and attached to a handle of hard wood (fig. 296). With this he traces a line across the glass, when a slight pressure on each side of the cut determines the fracture in the right direction. If the diamond be properly used, a true cut is produced, while a diamond with angles formed artificially gives only a scratch with ragged edges. The cut need not penetrate to a greater depth than the two-hundredth part of an inch. The glazier also uses a *hacking-out knife* (fig. 291), for getting out old putty; a *stopping knife* (fig. 288), for laying in and smoothing the putty; a *setting knife*, for setting glass in lead work; a *square* (fig. 297), a *straight edge* (fig. 300), a *two-foot rule* (fig. 295), a pair of *compasses*, for dividing the large sheets or *tables* of glass to the proper sizes, a *hammer* (fig. 294), for the sprigs, and a *brush* (fig. 301), for cleaning off his work. The notches in the glazing knife (fig. 288) are for breaking off any irregular or projecting bit of glass from the edge of a pane.

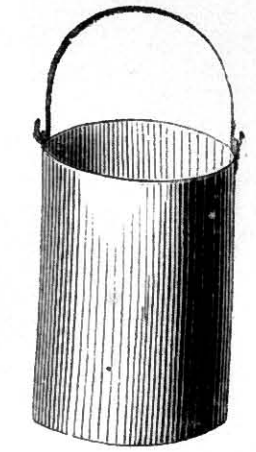

281, 282. PAINT BRUSHES.

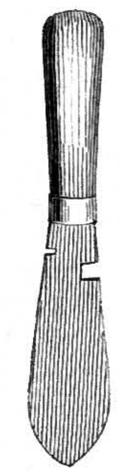

283. STOPPING KNIFE.


284. MULLER AND SLAB.

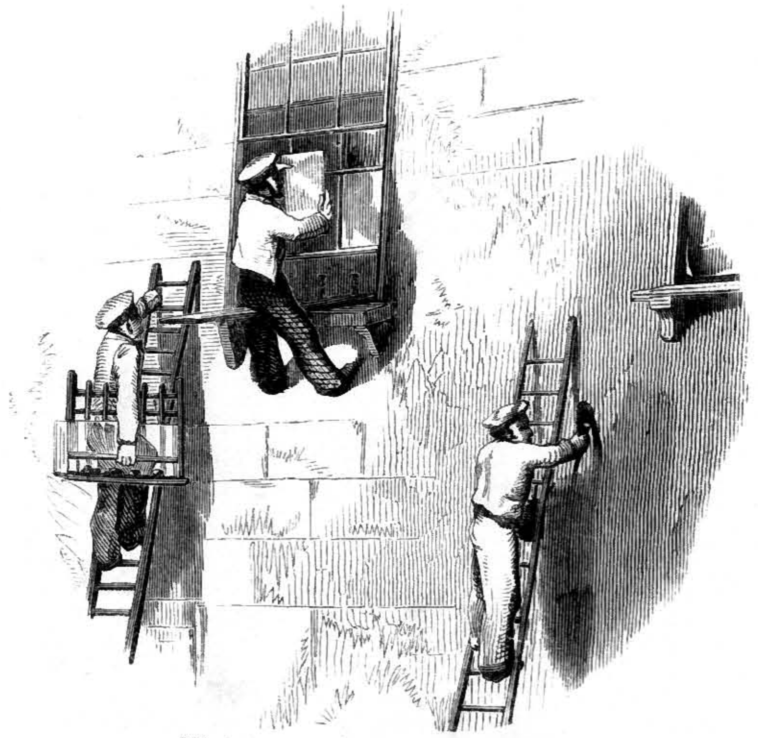

285. PAINT POT.

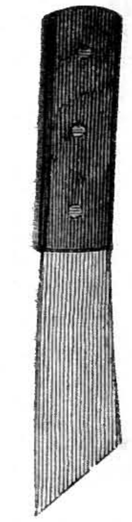

286. PALETTE KNIFE.


287. PAINT KETTLE.

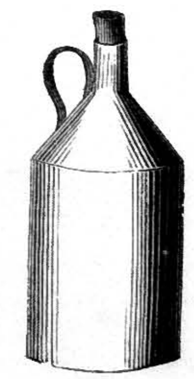

288. GLAZING KNIFE.

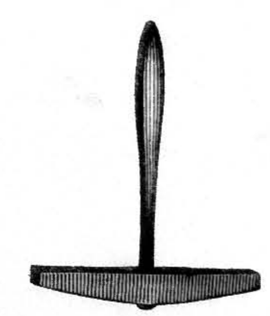

289. CHISEL KNIFE.

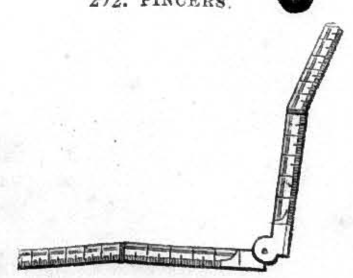

290. HOUSE-PAINTING AND GLAZING.


291. HACKING KNIFE.

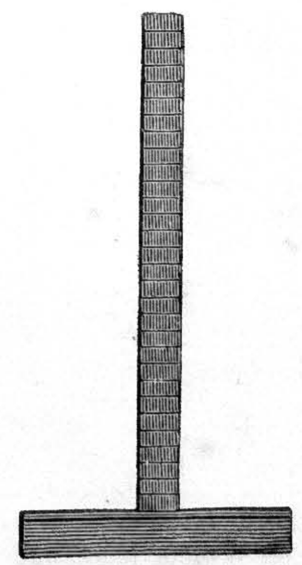

292. PINCERS.


293. OIL CAN.

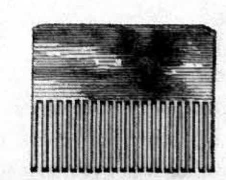

294. HAMMER.

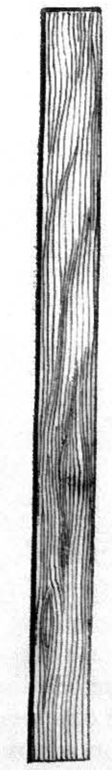

295. TWO-FOOT RULE.

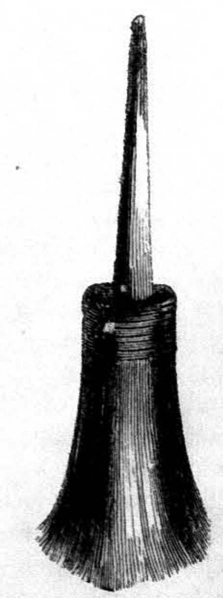

296. DIAMOND.


297. SQUARE.


298. PAINT POT.


299. GRAINING COMB.


300. RULE.


301. GLAZIER'S BRUSH.

XIV.—THE PAPER-STAINER AND PAPER-HANGER.

The practice of covering the walls of apartments with ornamental paper-hangings adds greatly to their comfort, and is not without its effect in promoting cheerfulness in the occupants. A room with a cold northern aspect is relieved by being papered with a rose or crimson colour, or with paper in which the warmer tints prevail; while a room with a bright southern aspect may be equally relieved by an admixture of a cold colour, such as a bluish green. The apparent size and height of a room are also influenced by paper-hangings: those with a large pattern reduce the apparent size: those with a large and flowing pattern reduce the height; but where vertical lines occur, even though the pattern be large, the height is not so much affected. A small room should not be covered with a large pattern, but both pattern and colours should be quiet and harmonious, and, like the background of a picture, should rather relieve and set off the objects in front and give repose to the eye. Sudden contrasts of colour should also be avoided, and it is generally in bad taste to attempt architectural effects, such as columns, friezes, pilasters, &c. Some of the most pleasing effects may be produced by means of flowers and conventional forms, and it has even been proposed to introduce short choice sentences from some of our best writers; but this would require the exercise of a sound judgment and good taste.

There are various methods of producing paper-hangings. An early method is that of *stencilling*, in which a piece of pasteboard or sheet metal with a pattern cut out in it was placed on the paper, or even on the whitewashed wall of the room, without the intervention of paper, and water colours being brushed over the back of the stencil would pass through the openings and produce the patterns on the paper or wall. When the first colour had become dry, a second stencil could be applied with a second colour, and in like manner a third and a fourth, and thus by the repeated applications of the stencil-plates the wall would be furnished with a pattern in a number of colours.

Another method of producing paper-hangings is by hand-printing, a process which closely resembles calico-printing by hand, and floor-cloth printing, as described in our *Illustrations of Manufactures*. The pattern is contained on blocks of pear-tree or sycamore, mounted on poplar or pine-wood (figs. 308, 310). Each block has four pin-points at the corners to serve as guide-marks in placing the blocks with other colours. Each colour is distributed over a sieve or drum of calf-skin (fig. 316), floating in a tub of water, thickened with parings of paper from the bookbinder's.

An attendant keeps the drum well covered with colour, and the printer, pressing the block upon the skin, transfers it to the paper and presses it down with the assistance of a lever worked by the foot (fig. 309). When the piece has been printed in one colour, it is hung up to dry. The *crutch* (fig. 314) is useful in hanging up or taking down the paper-hangings. *Flock paper* has the pattern first printed in size and varnish, and before this is dry, coloured flock, prepared from wool, is dusted over it. The flock is obtained from the shearing machines of the woollen cloth manufacturer. Unless already coloured, it is scoured and dyed to the proper tint, then stove-dried, ground to powder, and sifted. It is next placed in a large chest or drum (fig. 304), and the flock sprinkled over it. When about 7 feet of paper have been drawn in, the lid of the drum is closed, and the calf-skin bottom beaten with rods. This causes the flock to rise in a cloud, which as it subsides falls uniformly on the paper. Gradations of colour in the flock are afterwards produced by applying shades in water-colour or in distemper.

Paper-hangings are also produced by cylinder printing, in which as many as from 14 to 20 colours are produced, and one machine is capable of producing from 1,000 to 1,500 pieces in a day.

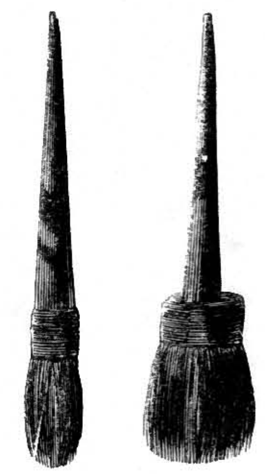
A piece of paper is 12 yards long and 20 inches wide, and when hung covers 6 feet superficial.

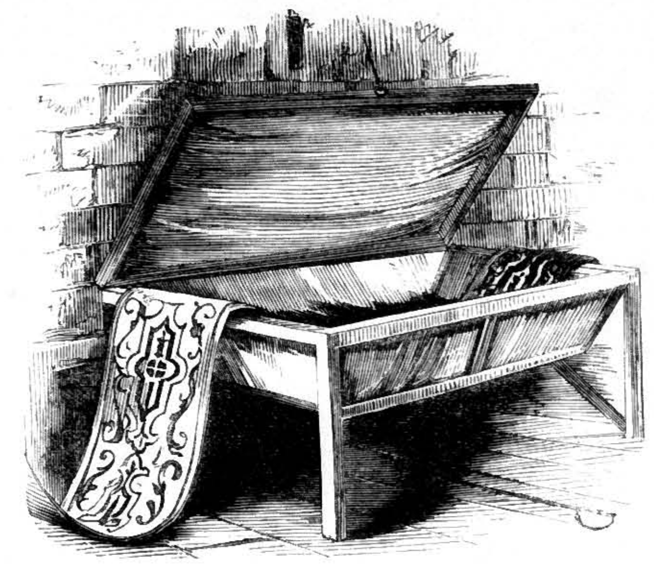
Our artist has represented several things that are not peculiar to this trade, such as *brushes* (figs. 302, 303), a *paint pot* (fig. 306), a *size can* (fig. 307), &c. The *spat* of wood (fig. 312) is a wedge for scraping the colour off a surface. The *colour mill* (fig. 315) is a common form of colour-grinding machine, consisting of two stones for each colour, arranged as in grinding corn (fig. 104). The upper stone or *runner* moves on the lower or bed stone. The colour is poured into an opening in the runner, finds its way between the two stones, and is gradually ground outwards to their edges, and escapes by the channel attached to the tin boxing which surrounds the stones. In fig. 315 two sets of stones are represented.

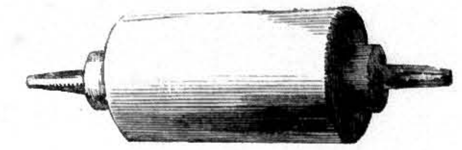
XV.—THE TAILOR.

Having noticed some of the more important trades connected with the preparation of food and shelter, we proceed to give a few details respecting one or two trades concerned in the preparation of our clothing. In our *Illustrations of Manufactures* we showed the various modes by which woven fabrics are prepared, not only as it respects the different textile fabrics of cotton, linen, silk, and wool, but also the peculiar kind of weaving by which hosiery is prepared, and the art of felting, by which beaver hats are produced. The method of making silk hats was also explained. The processes by which various kinds of leather are prepared were also illustrated. It will be seen from those details how large and important a part of our national industry is concerned in the preparation of clothing. The trades which are concerned in the cutting out and otherwise preparing the materials furnished by the manufacturer are numerous, and employ a large number of persons of both sexes. Thus, in the preparation of female attire the milliner prepares the lighter portions, such as bonnets, caps, collars, cuffs, fancy pelerines, capes, &c.—the dressmaker is chiefly employed in the preparation of ladies' robes, and the mantle-maker prepares the mantles and outer clothing. All females, however, are or ought to be acquainted with the use of the needle, from the child who makes clothing for its doll, to the matron who fabricates with her own hands a great portion of the wearing apparel of the females of her household. With respect to articles of men's attire, the case is different: they are prepared by persons who have been regularly trained and instructed in the tailor's art, and there is scarcely any attempt made at the domestic manufacture of their outer clothing.

It is difficult to explain in writing processes which depend so eminently on skill of hand, and that peculiar dexterity or *right-handedness*, as the word means, which can only be acquired by

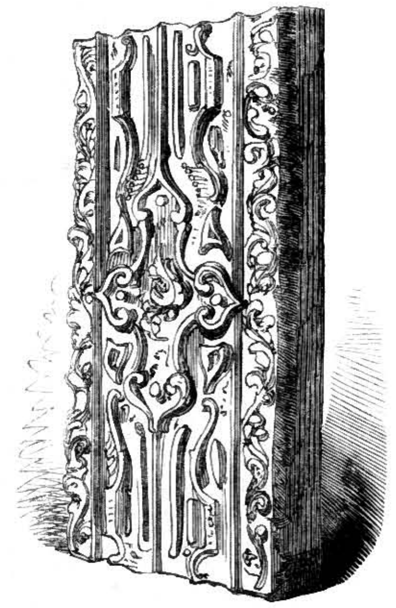

302, 303. PAINT BRUSHES.

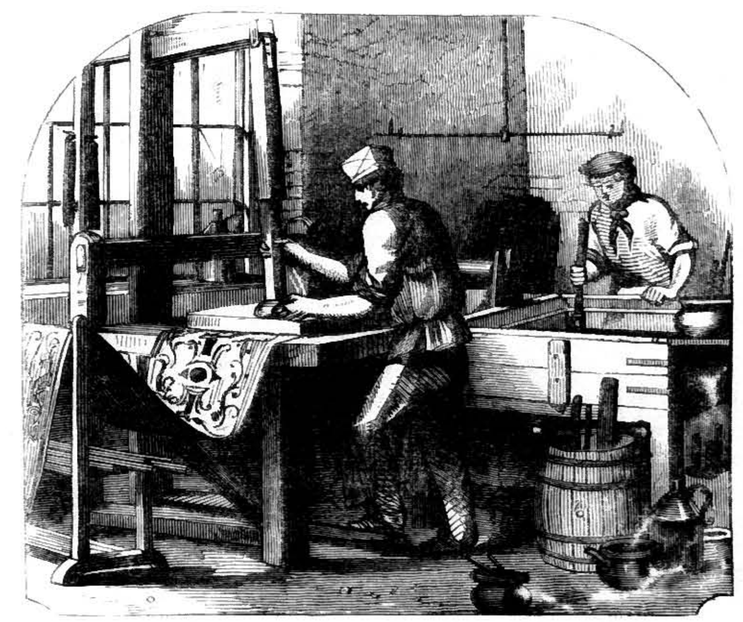

304. DRUM FOR LAYING ON FLOCK.

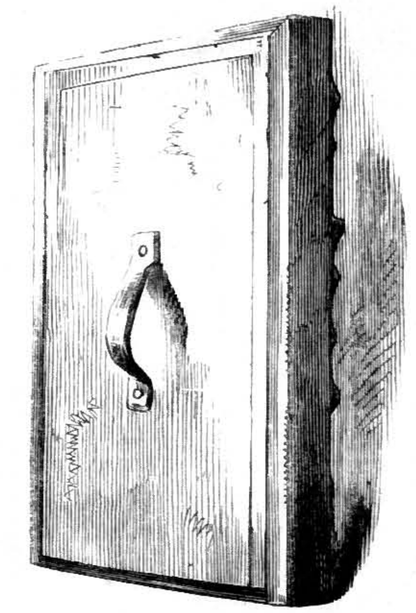

305. COLOUR DRUM.


306. PAINT POT.


307. SIZE CAN.

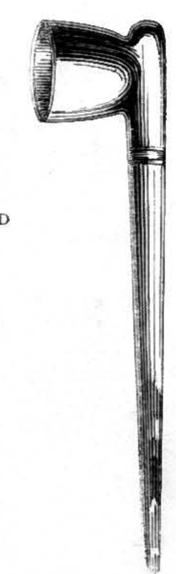

308. FRONT OF PRINTING BLOCK.

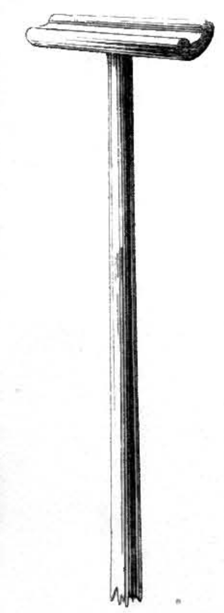

309. PRINTING PRESS.

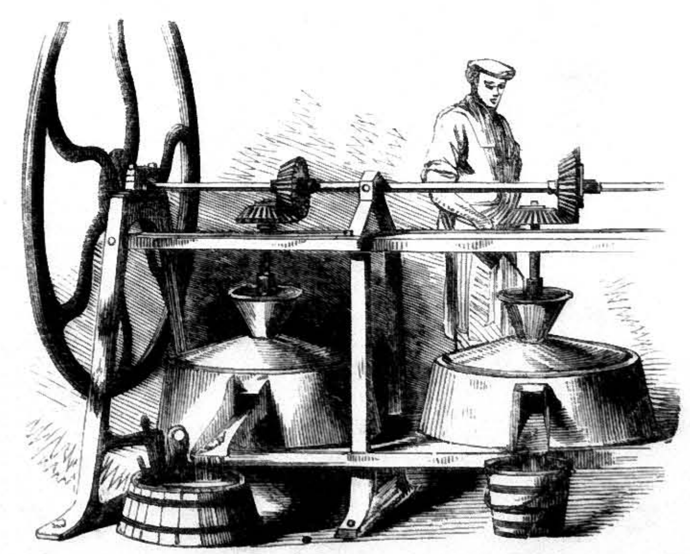

310. BACK OF WOODEN BLOCK FOR PRINTING.

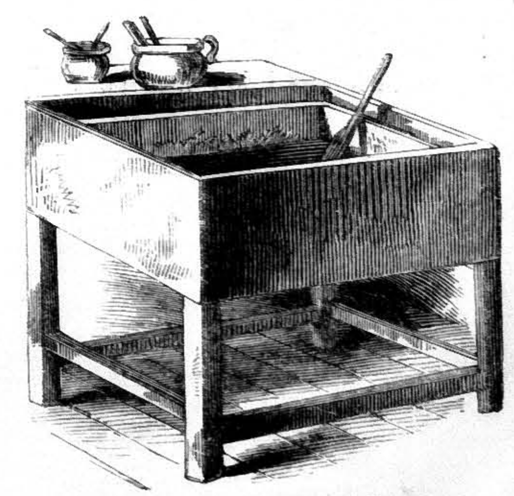

311. HAND BRUSH.


312. SPAT.


313. LADLE.


314. CRUTCH.

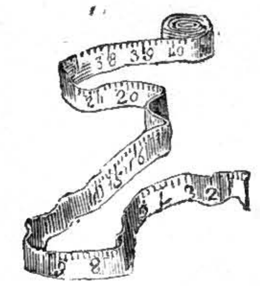

315. COLOUR-GRINDING MACHINE.


316. COLOUR SIEVE.

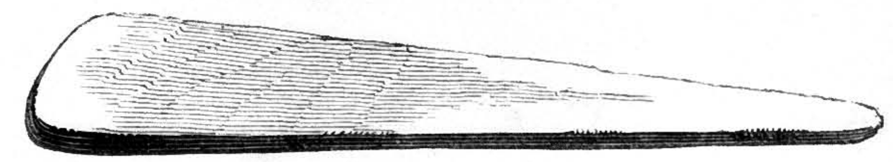
constant practice. The first step in preparing a suit of clothes is to ascertain the proper dimensions by applying a flexible *measure* (fig. 317) to the various parts of the body of the person for whom they are intended. In measuring for a waistcoat, all that is necessary is to ascertain the length, and the size round the breast and round the waist. The measures for coats and trousers are more difficult. For a coat the following dimensions must be taken:—1, the length of the waist; 2, the length of the coat; 3, the distance from the middle of the back to the elbow, and from thence to the bottom of the sleeve; 4, the size of the arm at the top, just above the elbow, and also at the wrist; 5, the length of the front, measuring from the top of the back seam to the bottom of the lappel; 6, the size of the breast just under the arms; 7, the size of the waist; 8, the height of the collar. These dimensions being taken, and entered in the *measure-book* (fig. 330), and the customer having selected the proper pattern from the samples submitted to him in the *pattern-books* (figs. 324, 331), the next step is to cut out the cloth, for which purpose it is spread out quite smooth upon a cutting board; the various parts are marked out with *chalk* (fig. 328), with the assistance of the *rule* (fig. 332). The next step is cutting out by means of the *shears* (fig. 319). This is a difficult art, and forms a distinct branch of the trade, many men earning their living solely by practising it. The work of the tailor, properly so called, is very simple. His tools are few and inexpensive. He requires a yard of linen for a *lap-cloth;* two pairs of *scissors*, one pair moderately large for common use, and the other small, for cutting out button-holes; a *thimble* (fig. 329), a piece of *bees-wax* (fig. 333), for waxing his thread; needles and thread (figs. 334, 335), a *sleeve-board* (fig. 318), an *iron* and a *holder* (figs. 322, 321), and a *goose* and *stand* (figs. 323, 326). The goose is so called from its handle, which resembles the neck of the well-known bird.

There are various kinds of stitches used by the tailor, such as the *basting-stitch*, which is long and slight, usually intended to keep the work in its proper position while being sewed; the *back* and *fore-stitch*, in which the needle is first put through the cloth, and turned up in as short a space as possible, so as to make a neat, strong stitch; it is then put through the cloth again in the same place, and again turned up, so as to pass through the cloth as before: the seam is finished by a series of such stitches. The back-stitch is sometimes used without the fore-stitch. Then there is the *side-stitch*, used for the edges of garments, in which the needle is passed through the cloth a little above or below the place from which it last came out. Then there is the *back-pricking-stitch* and the *fore-pricking-stitch*, in which the needle is first put entirely through, and then passed back again, so as to hold the cloth securely on each side. The *serging-stitch* is made by passing the needle through the cloth from the under to the upper piece, throwing the thread over the edges so as to keep them closely together: it is also used in joining selvages. The *cross-stitch* consists of two parallel rows of stitches, so placed that the stitch in the upper row may be opposite the space in the lower one, the thread passing from one stitch to the other in diagonal lines; it is used for keeping open the seams of such garments as require washing, and also for securing edges from ravelling out. In the *button-hole stitch*, the needle is first put through the cloth from the inner to the outer surface, and before it is drawn out, a twist is passed round the point, and when it is drawn out, a kind of loop or *purl* is formed at the top or edge of the opening. To increase the strength of this stitch, and to assist in making it true, a *bar* is formed on each side of the opening, before working the hole. This bar is made by passing the needle from one end of the opening to the other several times, upon which the hole is worked, the bar being kept as near the edges of the opening as possible. In the *hemming-stitch*, the needle is not inserted deeply, but in such a manner that the stitch is scarcely visible on the other side of the cloth. The *filling-stitch* is like the hemming, only in hemming the point of the needle is directed away from the workman, but in filling it is directed towards him. This stitch is used for sewing on facings. *Stotting*, pronounced *stoating*, is the stitch used for joining pieces of cloth so as to conceal the join. The pieces are not laid one upon the other, as in back stitching, but are placed side by side with the edges carefully fitted, and the needle is passed half through the thickness of the cloth. The stitches must be kept as near the edge of the cloth as possible: the needle is put in on the nearer edge of the two, and not slanted, but put as straightforward as possible. This stitch is used for joining the pieces of cloth for facings, collar linings, and other fillings up on the inner sides of garments, and also for preventing too much of the cloth from being taken up, if a back-stitched seam were made. *Rantering* is also intended to conceal a join: the seam is first made with a fore stitch, and over this the rantering stitch is made. Very fine silk thread is used, or twist, with one of the strands taken out, and a long and slender needle. *Fine drawing* resembles rantering, and is mostly used for closing places that have been torn. *Overcasting* is used to secure the edges of thin and loose fabrics from ravelling out. There is also a peculiar stitch required in making cloth buttons, but these are for the most part made by machinery, as described in our *Illustrations of Manufactures.* Indeed, machinery bids fair to supersede a large amount of the tailors' hand labour: already the *sewing machine*, as it is incorrectly called, is in extensive use for stitching the seams of trousers and similar work. But as this machine is also used by bootmakers, saddlers, dressmakers, and others where stitching is required, we defer our illustrated description to the end of this volume.

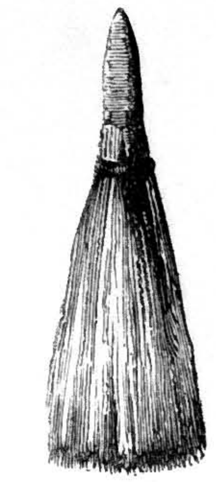
In making up a suit of clothes, the workman is guided by certain chalk marks made by the cutter-out, as for example, in the pieces required for a waistcoat, there may be two chalk lines, one running across to indicate where the pocket-holes are to be cut, and the other going down the front to mark the distance from the edge at which the buttons are to be put. All seams require to be well pressed with a hot iron, and projecting parts neatly pared, for which purpose the sleeve-board is useful. When the garment is finished, the glossiness produced by the iron should be wiped off, and the coat brushed.



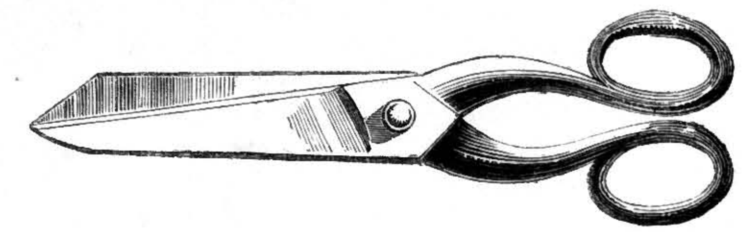
317. MEASURE.



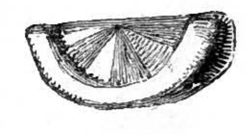
318. SLEEVE BOARD.



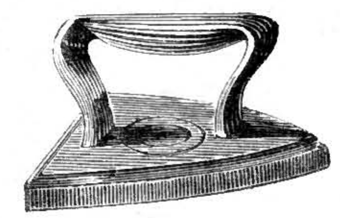
320. WHISK.



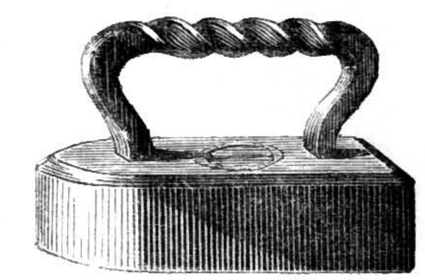
319. SHEARS.



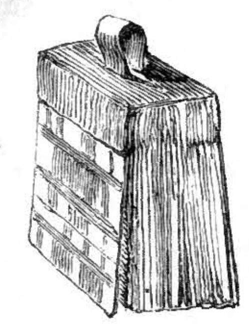
321. IRON HOLDER.



322. FLAT IRON.



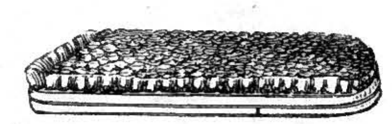
323. GOOSE.



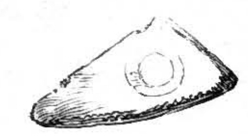
324. COAT PATTERN BOOK.

325. WORKSHOP.

326. GOOSE STAND.



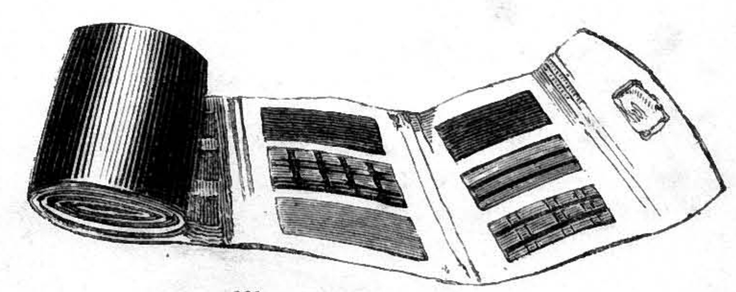
327. HARD BRUSH.



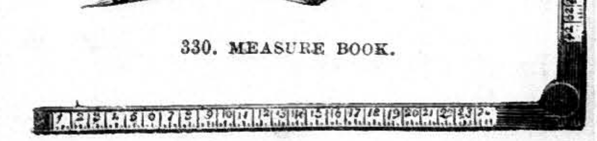
328. FRENCH CHALK.

329. THIMBLE.

330. MEASURE BOOK.

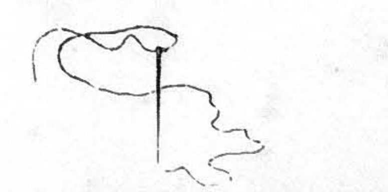


331. TROWSERS PATTERN BOOK.

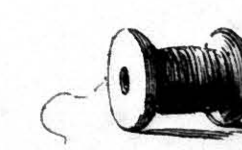


332. RULE.

333. WAX.



334. NEEDLE AND THREAD.



335. REEL.

XVI.—THE SHOEMAKER.

The trade which prepares coverings for the feet is much subdivided. Thus we have the *shoe-closer*, generally a woman, whose business it is to prepare the upper leathers of shoes; the *shoe-man*, who fixes the soles to the upper leathers; the *boot-closer*, who prepares the leg and *vamp* of the boot; the *boot-man*, who fastens on the soles; the *blocker;* the *clicker;* the *runner;* and the *cleaner*. For women's shoes there is the *binder*, who is a woman; but the shoes themselves belong to the *women's shoes maker*, to which belong the *sew-round man*, the maker of *women's welts*, and some others.

The shoemaker's tools and materials form collectively the *grindery*. This term originated in the circumstance that formerly the man whose business it was to sharpen the shoemaker's tools found it to his advantage to collect in his grindery or shop the hemp, the flax, the wax, the hairs, the tools, and stone rubbers used in the trade. The tools of one individual shoemaker form what is called his *kit*, and they consist of *pincers* (fig. 337), *nippers, hammer* (fig. 348), various kinds of *awls* (fig. 355), *seat* or *setting irons* (fig. 343), and other articles. The shoe-closer requires a slip of board to fit or prepare her work on, a pair of *clams* (fig. 339), or two tall nipping pieces of stave-like timber, which are held together between the knees; a block, or nearly half-round clump of wood, which is held on the left thigh by the *stirrup* (fig. 336), a *knife;* two differently sized *closing-awls;* and a *stabbing-awl;* two or three *seam-sets*, a *case of needles* called *short blunts;* a *thimble;* and some *silk twist;* while for the hem or whip on the linings, *common sewing silk*. Also some *paste*, contained in a horn (fig. 351), a little *flax* for the coarse or strong work; and *gum arabic* dissolved in ink or water. The seam is closed by joining the two shoe quarters and the vamp together, and also the back part of these quarters. The *flat* seam, or *outside* seam is employed, the *inside* seam being used on inferior work.

The lining is also done by women, thatf or the quarters being of some lively coloured roan or morocco, with abundant stitches. After the lining the *upper* has to be *set;* the *flat-seam-set*, or, if stabbed, the *stabbing-side-set*, is heated at a candle, and a solution of gum being rubbed on the seam, the set is briskly and forcibly pressed along the line of stitching. It thus becomes polished and hardened, and is ready for the maker or shoe-man. After the closing, the shoe goes through various operations, such as the *lasting* or tacking of the upper leather to the *in-sole*, the sewing in of the *welt*, the stitching to this welt of the *out*, or *top-sole*, the *building*, and sewing down of the heel, and, lastly, the *setting* or *taking-off*. After this the shoe has to be *rounded*, or pared round the quarters, and across the top of the vamp. It is then bound, and, lastly, polished or cleaned up.

In making a boot, the *clicker*, or cutter, having given the proper form to the vamps, legs, &c., the *closer* does his work. The closing is the most delicate operation in the trade. The seam is made by means of waxed threads, to the ends of which are attached hairs or bristles for their ready insertion into the holes made by the awl. In what is called *stabbing* the portions of leather are stitched directly through, either in straight or curved lines. The work is held either in the clams or between the knees, and receives the awl at the right side piercing through to the left or inner side, from which the left-hand hair should be at once protruded, the right-hand hair being put in afterwards, and the stitch being then drawn smartly in. This is called *blind-stabbing*. The term has been explained by Mr. Devlin, in "The Shoemaker," published in Mr. Charles Knight's Guide to Trade. He says, "Quickly goes in the awl, and as quickly out again, but not before the hair from the fingers of the left hand has found the passage, without being at all directed by the sight, but literally in the dark, and hence the term *blind-stabbing*, the right-hand hair immediately following in the opposite course, the closed thumb and forefinger of either hand nipping at the moment the hairs from these different directions, and drawing the same as instantly out, at once completing the stitch." A proficient closer will, in half an hour, stab the four side rows and the two back rows of the counter of a boot, making about twenty stitches to the inch, the entire work averaging about thirty inches. Mr. Devlin says that he has made as many as sixty stitches in the inch.

The work next goes to the boot-man, who makes or attaches the sole. This is more difficult than in the case of the shoe. The lasting is more difficult; a *rand* is made to the heel, or what is called the *French seat*, and this with the *shank piece*, or strengthener between the inner and outer sole, which runs along the waist of the boot, are additions not to be found in the shoe.

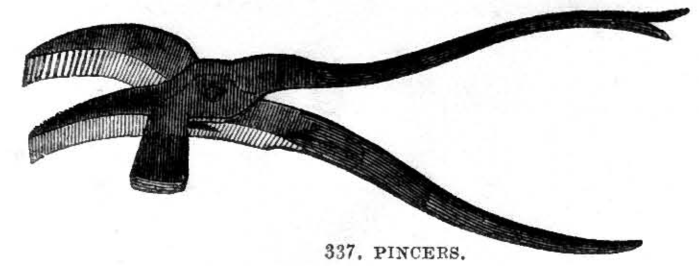
The master shoemaker or his clicker takes the required measures, chooses the materials, causes the Wellington fronts to be blocked, fits up the lasts, cuts out the work for the closer, prepares and sorts the sole or bottom stuff for the maker, examines the workmanship, and polishes up the boots.

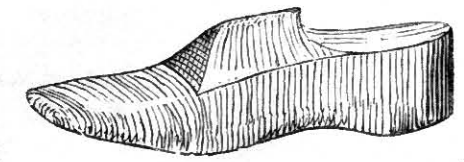
Women's common or welted shoes resemble men's. The man's and woman's single-soled shoes or *pumps* are also similar.

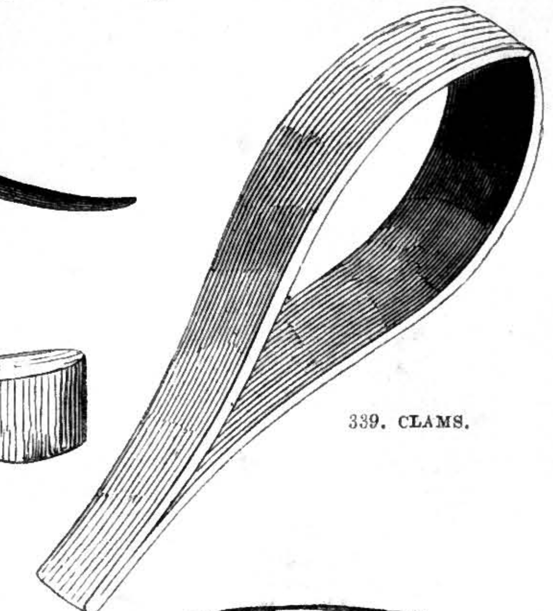
There are several finishing processes, such as *paring* by means of the *knife* (fig. 352), *rasping* with the *rasp* (fig. 350), and *scraping* with the edge of a piece of glass. The tool, fig. 341, is for setting up and polishing the fore-part stitch. The *jigger*, as it is called, is used with a little soap rubbed along the stitches. A solution of gum is also employed. The ridge left by the jigger is sometimes slightly filed from the sole towards the edge where the leather turns over a little, forming what is called the *crease*. This is rubbed with the *fore-part iron* (fig. 340), which forms it into a hard wire, and produces a firm, glossy edge. The *seat iron* (fig. 343) is used to set or harden the lower part of the heel.

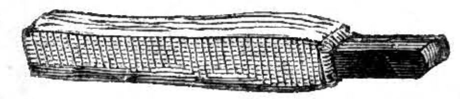
The *glazing iron* (fig. 342) is also used for polishing the sole. The *lap-stone* (fig. 353) is a smooth stone, on which the sole leather is condensed and made more durable by hammering it with the broad face or pane of the hammer (fig. 348). The fine polish on the upper leather is produced by straining the shoe on a last (fig. 338), and rubbing it with the polishing stick (fig. 354), a good kind of blacking being previously applied.


336. STIRRUP.


337. PINCERS.


338. LAST.


339. CLAMS.

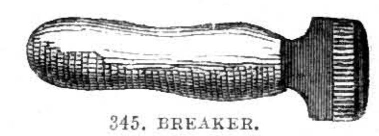

340. FORE-PART IRON.

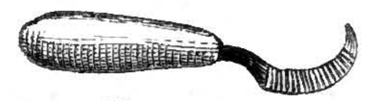

341. JIGGER IRON.

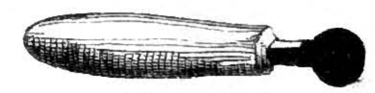

342. GLAZING IRON.


343. SEAT IRON.


344. BEVEL IRON.


345. BREAKER.


346. SEAT FILE.


347. JIM CROW.

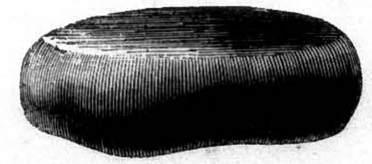

349. SHOEMAKERS AT WORK.

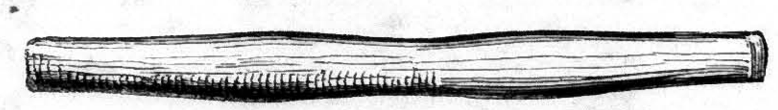

348. HAMMER.


350. RASP.


351. PASTE HORN.


352. KNIFE.


353. LAP STONE.


354. POLISHING STICK.


355. AWL.

XVII.—THE CABINET-MAKER AND UPHOLSTERER.

It is the business of the cabinet-maker and upholsterer to prepare the furniture of rooms, such as tables, chairs, drawers, &c., and most of the operations of preparing the wood are performed at a *bench* (fig. 371). This is made very strong, the joints being connected by means of screw-bolts and nuts. The surface is made flat and true, and there is a trough for holding small tools. One of the chief operations performed at this bench is the planing of wood, for which purpose the plank or other article is laid on the surface, and is prevented from slipping by means of the iron *bench-hook, h* (shown in a separate figure, 366). This has teeth which hold the wood, and prevent it from moving sideways; but as these teeth might injure a nearly-finished article, there is a square *wooden stop, w* (shown separately, fig. 369); *i i* are other stops (see also fig. 370). All these stops fit in mortices, and can be placed at any required height, or depressed, so as to be flush with the bench. At the side of the bench are two *screws, s* and *s′*, which, with the *chop, c*, form a vice; the screw, *s*, simply presses the wood, and the screw, *s′*, is furnished with a piece, *g*, shown detached, called a *garter*, which goes into a groove in the neck of the screw, *s′*, so that when both screws are opened, the screw, *s′*, serves to bring the chop, *c*, outwards. The chops open many inches, and hold work by the sides or edges, so that small boxes, drawers, and other work can be held between them. The end-screw, *e*, draws out the sliding-piece, *p*, and serves to hold thin works, and also works by the two ends, and is useful in making grooves, rebates, and mouldings. The holes in front of the bench are for an iron stop, *i*, the face of which is slightly roughened, and there is a similar stop in *p*, so that on placing pieces between these two stops, they will be held securely by turning the screw, *e*. There is also an iron holdfast, *o*, the straight arm of which fits into a hole in the bench, and it is useful for holding squared pieces of wood, when making mortices or dove-tails: the work is fixed by a blow on the top at *o*, and is released by a blow at the back at *l*. There is a pin in one leg of the bench at *p*, for fitting into one of the holes in the same leg, for supporting the end of long boards, the other ends of which are fastened by the screws, *s*, *s′*.

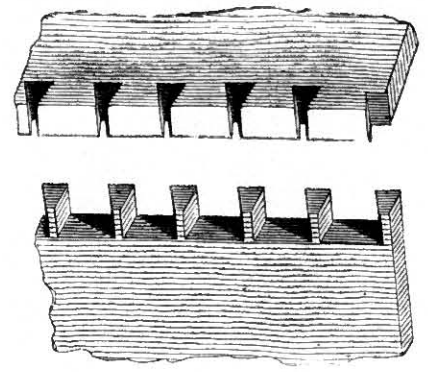
The planes in general use are the *jack-plane*, for coarse work, the *trying-plane*, for giving the work a better figure, and the *smoothing-plane*, for finishing the surface. The plane is furnished with a *toat* or *handle*, which is held in the right hand, the front being grasped with the left, and the body of the workman is pressed down on the work, so as to throw part of its weight on the plane. The best planes are furnished with a double iron (fig. 360), united by a screw, but the lower piece is alone used in cutting, the upper or *top-iron* assisting the ascent of the shavings. The *plane* (fig. 377) is a form in common use on the Continent, the projecting handle or *horn* being held in the left hand, while the right is placed on the back of the stock. Grooves, mouldings, rebates, &c. are made by means of planes of the required form, so that the iron may cut out the wood as it moves along. (See fig. 368.)

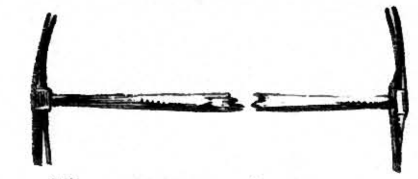
Among the joints used by the cabinet-maker, none is more common than the *dove-tail*, fig. 358. Such joints are used for joining the ends of boards at right angles with each other, as in boxes, drawers, &c. In toys and common works, a kind of sham dove-tail is used, by planing the edges to be united at an angle of 45°, slightly securing them by glue, and then making upon the angles with a back-saw a few cuts, leaning alternately upwards and downwards: pieces of veneer are then glued and drawn into the notches. The work is then said to be *mitred and keyed*, and the whole is tolerably strong. Fig. 356 shows the separate parts of the common dove-tail joint, the lower board showing the pins, and the upper the dove-tails. In cabinet-work it is usual to make the dove-tails on the front or more exposed part of the work, and the pins are cut of only one-fourth the size of the dove-tails, so that but little of the end wood may be seen. To produce close joints, nice work is required. The work is neatly set out or marked, and the cuts are made with the *dove-tail saw*, which is one of the numerous saws with backs to keep the blade straight. The wood between the dove-tail pins may be cut out with a *bow* or *turning-saw*, which is a small saw set in a frame also for the purpose of keeping it straight, and the spaces are pared out with the chisel, driven with the mallet. The pins are usually made first, and the dove-tails are marked from the pins. The gauge lines should be left in sight; so that the dove-tails may be a trifle too small, so as to compress the pins, and produce a close joint.

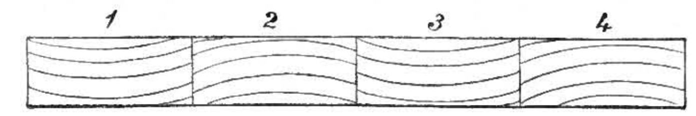
The cabinet-maker uses a variety of boring tools, the simplest of which is the *brad-awl* (fig. 372), and the *awl* (372*). The brad-awl is a cylindrical wire, with a chisel edge, but it is sometimes sharpened with three facets. The awl is square and sharp on all four edges and gradually tapers off until near the point, when the sides meet more abruptly. Most of the boring tools used in carpentry are fluted to make way for the shavings, and they are sharpened in a variety of ways. The *gouge-bit* (fig. 361), also known as the *shell-bit* and *quill-bit*, is sharpened at the end like a gouge, and when turned round it cuts the fibres round the margin of the hole, and removes the wood nearly in the form of a solid plug. The *spoon-bit* (fig. 367) is usually bent up at the end, so as to make a taper point: it is in common use for making the holes for the wooden joints of tables, &c. The *auger-bit* (fig. 363), also known as the *nose-bit* and the *slit-nose-bit*, is slit up a small distance near the centre, and the larger piece at the end is then bent up nearly at right angles to the shaft, so as to act like a paring chisel. The *gimlet* (fig. 362) is also a fluted tool, ending in a pointed worm or screw, for drawing it into the wood while the chief part of the cutting is done by the angular corner between the worm and the shell. The latter gets full of wood, when the tool must be taken out to empty it. The *centre-bit* (fig. 364), of which three views are given, consists of three parts:—1, a centre, triangular point, or pin which serves as a guide; 2, a thin shearing point or *nicker*, for cutting through the fibres; and 3, a broad chisel edge or cutter, placed obliquely, for paring up the wood within the circle marked out by the point. There are a great many varieties of centre-bits: there are many boring-tools made with spiral stems, similar to the *twisted gimlet* (fig. 362), to enable the shavings to ascend the hollow worm, and thus save the trouble of withdrawing the bit so often. Of this kind is the *screw-auger*, fig. 365. There are an immense number of other tools which might be noticed, but we must refer the reader who desires to make their acquaintance to the second volume of Holtzapffel's excellent work on "Turning and Mechanical Manipulation."

In the preparation of furniture, the taste of the artist may often be called into exercise, not only in promoting beauty of form, but in various carvings and inlayings. The French are distinguished for ornamental cabinet-work, especially for their *marqueterie* inlay, or the inlaying of woods of various tints in the form of flowers, ornaments, &c.; as also for their *buhl-work* (so called from M. de Boule, a French cabinet-maker of the reign of Louis XIV.), in which metals are inlaid on grounds of tortoise-shell or ebony. In some cases, ebony cabinets are inlaid with precious stones, and a variety of woods and metals surmounted with carved figures, with perspective recesses, and innumerable drawers, &c. We may also refer to the art of *veneering*, or the covering of a common wood, such as the surface of a deal table, with a thin slice of some beautiful and costly wood, so as apparently to convert the deal table into a mahogany one. Marqueterie work, when applied on a bolder scale to the production of floors, is called *parqueterie*, and when applied to the decoration of wall panelling, it is known as *tarsia-work*. Of late years, porcelain panels have been inlaid in furniture with good effect.

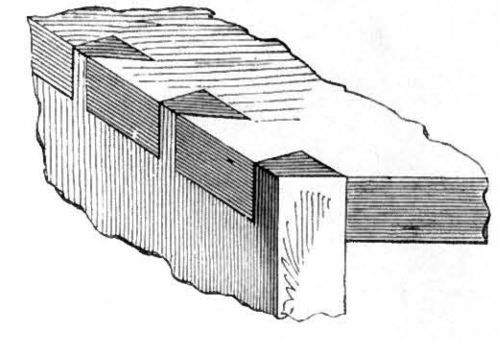
The work of the upholsterer usually follows, or is dependent on, that of the cabinet-maker, and a glance at the interior of his shop (fig. 376) will give an idea of the nature of his work.

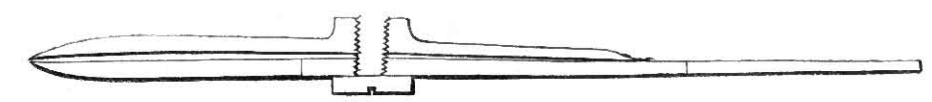

356. DOVE-TAILING.

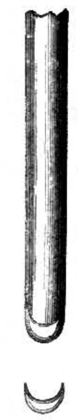

357. UPHOLSTERERS' HAMMERS.



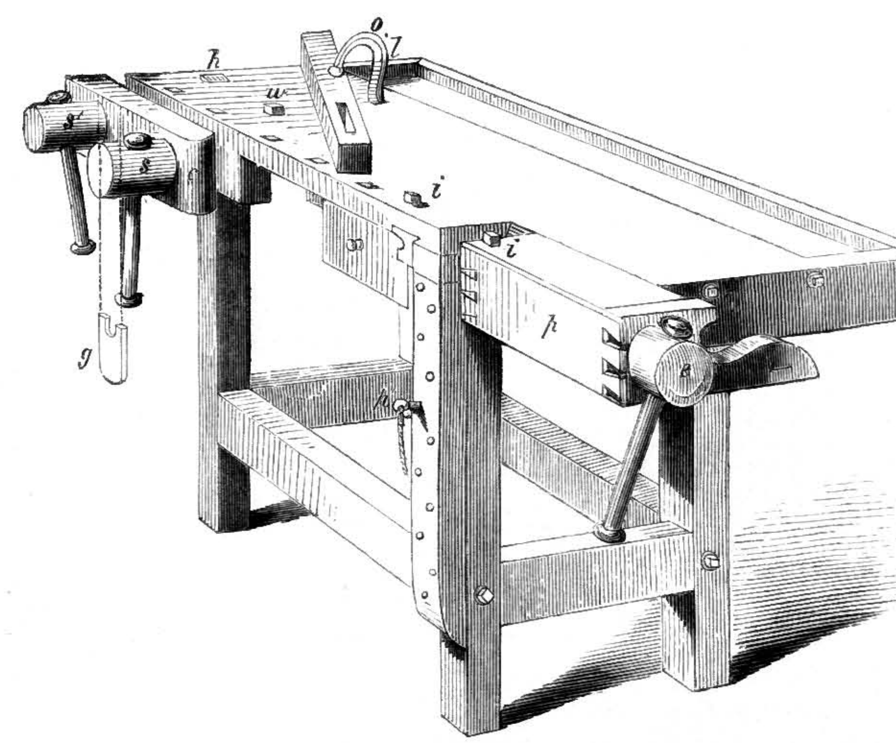
359. JOINING WOOD TO PREVENT WARPING.


358. DOVE-TAIL JOINT.

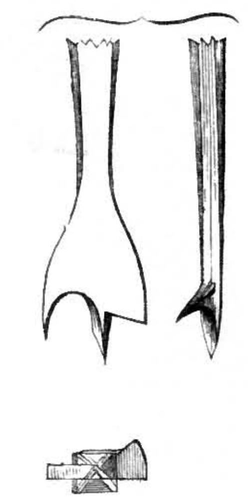

360. PLANE IRON.

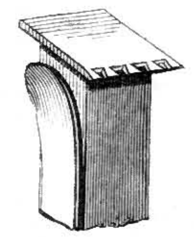

361. GOUGE-BIT.


362. TWISTED GIMLET.

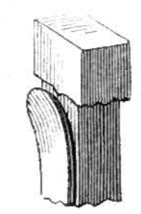

371. THE BENCH.

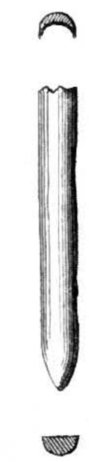

363. AUGER BIT.

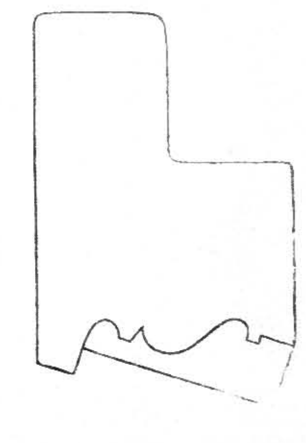

364. CENTRE BIT.

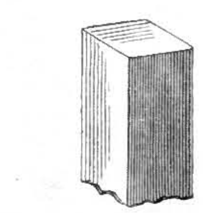

366. BENCH HOOK.

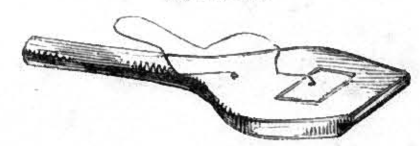

365. SCREW AUGER.

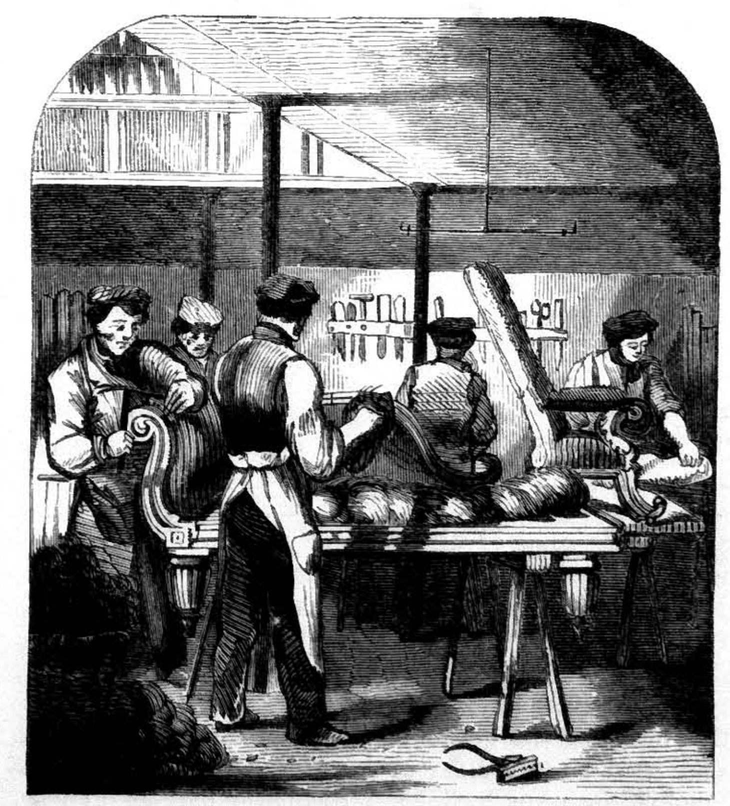

370. IRON STOP.

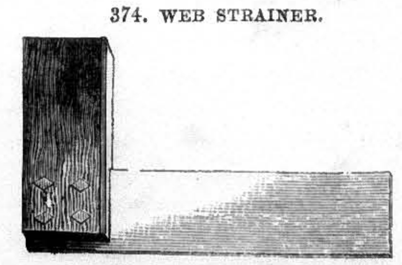

367. SPOON BIT.

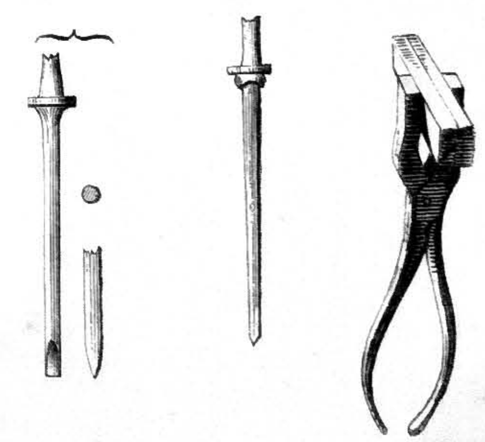

368. MOULDING PLANE.

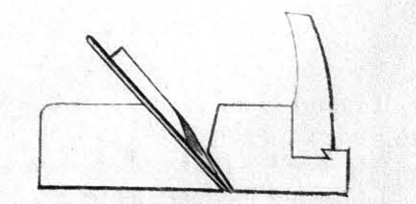

369. STOP.


374. WEB STRAINER.


376. UPHOLSTERER'S SHOP.


375. SQUARE.


372. BRAD-AWL. *372. AWL. 373. STRAINER.


377. PLANE.

XVIII.—THE TURNER.

The business of the turner is to shape wood, metal, and other hard substances, into round or oval figures, by means of a machine called a *lathe*. The art of turning is of very ancient date, and the potter's wheel, probably, the earliest form of lathe. But in this case the axis is vertical, instead of being horizontal. There are few machines more useful than the lathe, for by its means various parts of other engines and machines, and even tools, are produced. Indeed, nearly all solid objects in wood and metal, in which the circle or any of its modifications can be seen, are thus produced. In turning, the work is usually put into the lathe, and made to revolve with a circular motion about a fixed line or axis; it is worked to the intended form, by means of edge-tools presented to it, and held down upon a fixed rest. The projecting parts of the work are thus brought up against the cutting edge, and are cut off, whereby the outer surface is so reduced as to be at an equal distance from the axis of motion, and thus it has a circular figure. If the axis be made moveable during the revolution of the work, we may have *oval* and *rose-engine* turning. The work may be also turned hollow, and the outer surface may be fluted or grooved, and ornamented in a variety of ways.

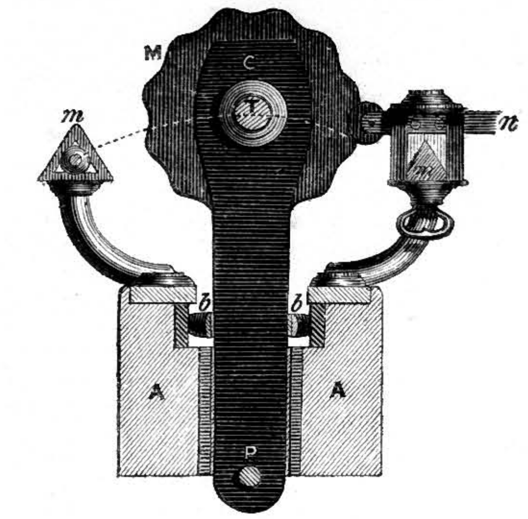
There are various descriptions of lathe, but it will be sufficient in this place to describe the *spindle* or *mandril-lathe* (fig. 382). The uprights, *A A*, support the bed, *B*, which consists of two bars of iron, with an intervening space. Attached to the bed is a cast-iron frame, *C D*, for supporting the spindle or mandril, *a b*. *E*, called the *back-puppet*, is used to support one end of the work, *G*, while the other end is fixed to the end of the mandril, and is turned round by it; *E* has a pin which enters the work, and the screw, *e*, pushes it forward, while a clamp-screw, *E*, binds the screw and adjusts it. That puppet is secured to the bed by a tenon which enters the groove, and is secured by a nut *f*: but when this is loosened, the puppet can be slid along the bed, so as to be adjusted to the length of the work. The neck of the mandril projects beyond the collar, and is furnished with a screw for receiving various pieces called *chucks*, each chuck being adapted to hold a different piece of work. The other end of the mandril is supported by a point, or in a collar. When made with a point, it is received by the end of a screw tapped through *D*, by turning which, the mandril can be adjusted. Motion is given to the mandril by means of a catgut band, passing round the pulley, *h*, and the large iron foot-wheel, *H*, attached to the axis, *I*. This axis has a crank in the middle, which is united by an iron link, *K*, to the treadle, *L*, which is fixed by three rails to an axis, *M*, on which the treadle moves. The lathe is set in motion by moving the wheel by hand, until the crank just passes over the highest point, when the motion can be continued by the foot. Attached to the bed is a rest, *N*, for holding the tools: it is secured by a nut, *K*, capable of being adjusted at pleasure. In turning cones or similar work, the edge of the rest is inclined to the axis of the work. Rests are made of different sizes, to suit different kinds of work: there is also a circular rest, which enables the turner to ornament balls and other round objects.

The turner uses a variety of gouges and chisels, some of which are represented in the figures. The gouges are first employed for roughing out and forming the work, and the chisels for smoothing and reducing it to the required form. The gouge is formed nearly half round to an edge, as in fig. 385, and the two extreme ends of this edge are sloped off, so that there may be no corners to catch in rough wood. In turning soft wood, the blade of the gouge is considerably inclined, as in fig. 385, but for hard wood a different kind of tool is employed, as in fig. 386, and is much less inclined. Other kinds of tools are shown in the figures, as in 387, for inside work, 394, for scooping out, and 392, for cutting screws, &c. Some of the tools represented are used in metal turning. For turning soft wood, the chisel is usually ground with a bevel on either side; but for hard woods, ivory, and bone, the cutting edges are bevelled only on one side, and the angle of the edge is obtuse. The turner also uses *calipers*, for measuring his work as it proceeds, and also *milling-tools*, or small wheels cut to a pattern, which, being pressed against the work while revolving, impresses a pattern on it. There are also various forms of chuck for holding the work, such as the *cup-chuck* (fig. 388), the chuck holding a centre-bit (fig. 389), and where great accuracy is required, the chuck (fig. 393), which is screwed to the mandril, while a projecting steel point, exactly in the centre line, receives the work, and holds it between it and the point at the back centre.

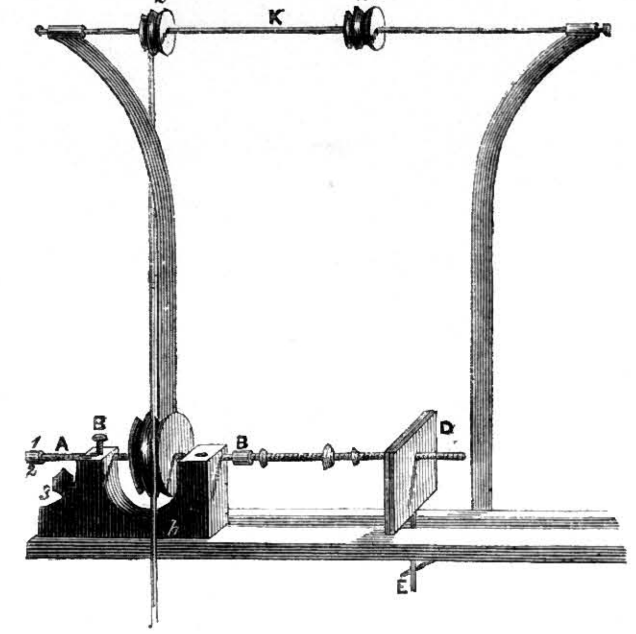
In cutting screws, a pattern screw, *a* (fig. 382), is fixed at the end of the mandril, which is arranged so as to move endways; the distance of the threads in the pattern corresponds with the screw intended to be cut upon the work, which is fixed in the lathe by a chuck. At *n*, is a piece of brass cut with threads adapted to the pattern-screw, and being drawn up against the pattern-screw, works into its threads, and in so doing, makes the mandril move endways with a screwing motion; so that if a cutting-tool be held steadily to the work, it will cut a spiral channel or screw upon it. In cutting screws *flying*, as it is called, the tool, fig. 392, is applied to the work, and moved along endways, so that the work, in turning round, will receive a spiral cut, but this is not so accurate a method as the former. Outside and inside screw-tools are used, as in fitting the screw top to a turned box, &c.

By using eccentric, oval, or elliptic chucks, a great variety of geometric patterns may be produced. Some lathes are furnished with what is called an *over-head motion*, fig. 379, and it is useful for ornamenting the sides, edges, or curved surfaces of work, but in such case it is the tool which revolves rapidly, and cuts the patterns, while the work remains fixed. The iron frame, fig. 379, is attached to the bench of the lathe, and in the front, above, is a spindle working in nuts, 1, 1, and attached to the spindle are a couple of wheels, 2, 2, the one on the left, situate over the fly-wheel of the lathe by which it is turned, while the other slips backwards and forwards, to adapt itself to the work; the ordinary catgut is removed from the fly-wheel, and a long one is passed over it, and over the small wheel, No. 2. The cutter is held in a slide-rest, and the other small wheel, No. 2, is brought over it and a catgut connects it with the small brass wheel, *B*, of the cutter. A metal wheel, graduated into 360 parts, each marked by a small hole, is used to regulate the patterns. The wheel is kept steady by a small steel key, *h*, slipped into a brass knob, while the other pointed end enters one of the small holes, and the work remains fixed, until the key is moved into another hole.

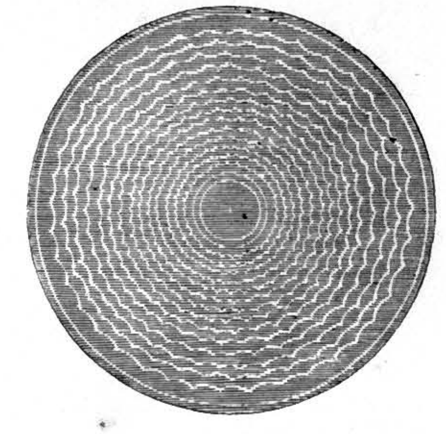
In rose-engine turning, or in the production of rosettes, such as fig. 380, the centre of the circle in which the work revolves, is made to oscillate with a slight motion while the tool remains fixed; for which purpose the mandril, M, fig. 378, is furnished with a variety of rosettes of different patterns, some of which are scolloped out as in the figure, the number of scollops varying from 12 to 144. The work is held in a chuck attached to the end of the mandril, *T*, and the standards which support the mandril are not fixed into the bed, but descend between the cheeks. The work is fixed in a chuck at the end of the mandril, and the tool is held by a slide-rest, while attached to the mandril is a metal rosette, for giving the required oscillating motion. The rosette is acted on by a small roller at the



378. ROSE ENGINE.

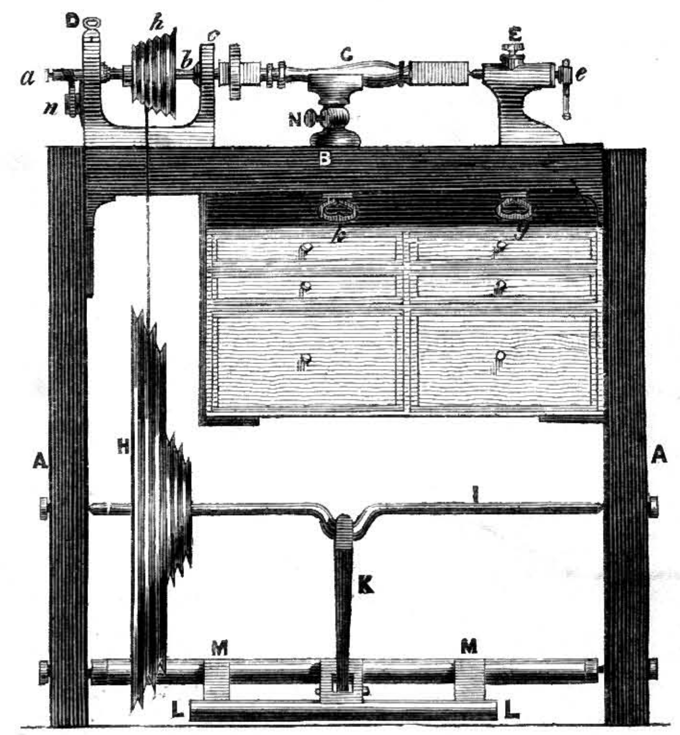


379. OVER-HEAD MOTION.

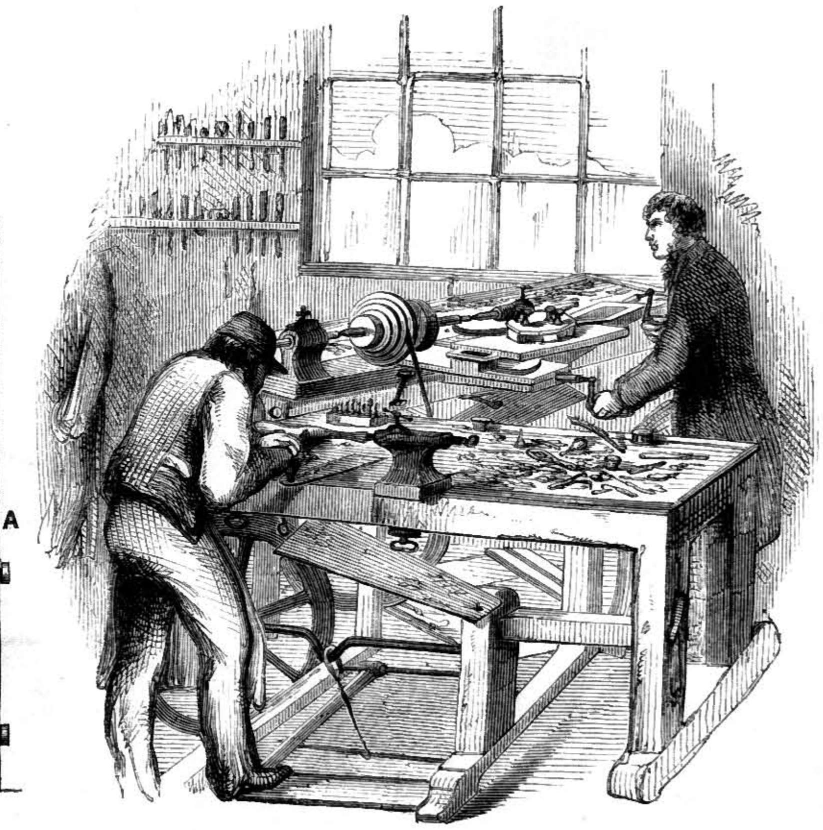


380. THE ROSE.

381. SHAPING TOOL.

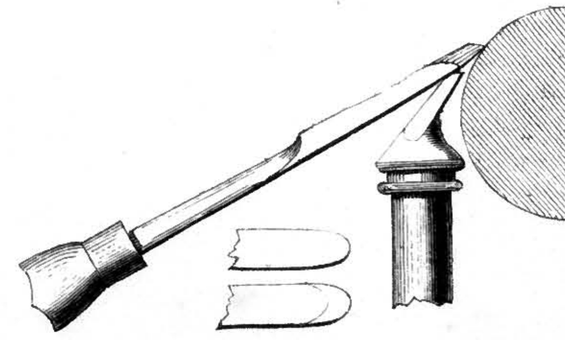


382. SPINDLE OR MANDRIL LATHE.

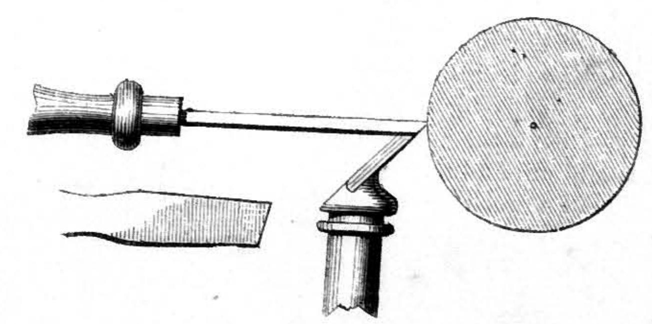


383. TURNERS AT WORK.

384. SMALL GOUGE.

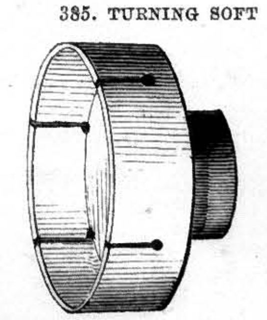


385. TURNING SOFT WOOD.

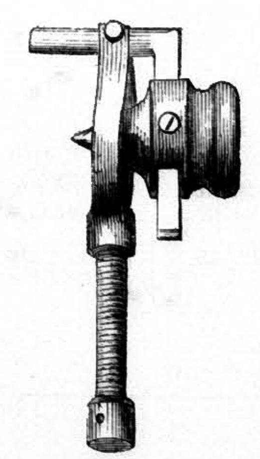


386. TURNING HARD WOOD.

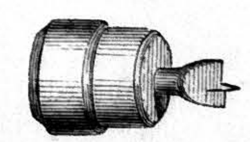
387. INSIDE TOOL.



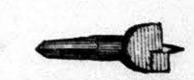
388. CUP CHUCK.



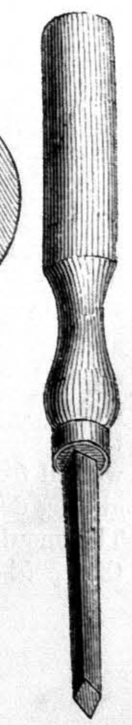
389. DOG AND CARRIER CHUCK.



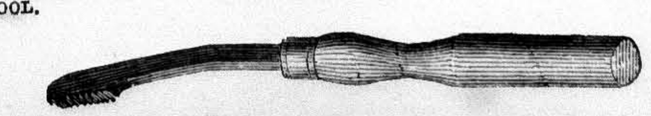
390. CHUCK AND CENTRE BIT.



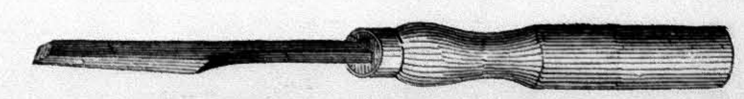
391. CENTRE BIT.



392. SQUARE TOOL.



393. SCREW TOOL.



394. SCOOPING OUT TOOL.

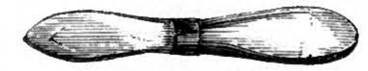
end of the piece, *n*, which is supported by a triangular bar, *m*. As the mandril revolves, the eminences and depressions of the rosette adjust themselves to the roller, and produce the oscillating motion of the mandril, while the springs, *b b*, restore the mandril to a vertical position, when disturbed therefrom by an indentation of the rose. Fig. 383 represents turners at work, the one on the left, in the ordinary manner, and the one on the right is managing the slide-rest, which holds the tool for more accurate work.

XIX.—THE PICTURE-FRAME GILDER.

The man who prepares picture and looking-glass frames, usually calls himself a "carver and gilder," by which it is understood, that he prepares, or causes to be prepared, the artistic work of the frame, as well as laying on the gold by which it is decorated, or supplying the plate-glass of the mirror, and the silvering at the back, by which it is made reflective. The fact is, that a number of trades are concerned in carving and gilding. It is rarely that an artist designs, still less executes, the carved work of a frame, on account of the costliness of artistic work by hand. Manufacturers are furnished with a set of moulds, by which they produce, by casting, any number of ornaments in plaster, composition, *carton-pierre*, *papier-maché*, &c. or the ornaments may be stamped in leather, embossed, coated with silver-leaf, and varnished with lacquer; and such has been the demand for the latter style of ornament, that the hydraulic press has been employed to produce it. A large number of ornaments are also executed by a machine in which a series of drills are pointed from a model, so that Gothic oak screens, dead game, foliage, &c. can be produced with great economy, the last touches being given by hand. All this is very different from the wood carving, which was formerly executed by real artists, such as Gibbons, a single work of whom we have known to produce upwards of 200 guineas. The gilder therefore has no choice but to purchase his ornaments ready made, and attach them to a plain frame, or to purchase the frame already ornamented in the rough, and finish it by gilding. In the same way the carver purchases the plate-glass properly silvered from the wholesale dealer, and mounts it in a frame suited to the taste and means of the purchaser. There are various articles of furniture which require the intervention of the gilder, such as window-cornices, gilt bordering for the top and bottom of a room, tripod-stands, flower-baskets, candelabra, &c. In some cases, as in the frames for prints, very little gilding is used, for, with the exception of a narrow beading, the whole is made of some ornamental wood.

The simplest gilt frame, such as a bevelled flat frame, may furnish an example of what is called *burnish-gilding*. The joiner supplies the gilder with moulding, in lengths of twelve feet, and the gilder gives one of these lengths a *priming* of hot size and whiting, called *thin white*. This being dry, holes and irregularities are filled up with putty, when a thicker coating of size and whiting, called *thick whiting*, is laid on, and to prevent the fine hollows from being filled up, the edge of a crook or chisel is drawn along them. Other coatings are also laid on, after which the opening tools are again used, and a smooth surface is produced by means of one of the burnishers, consisting of hard smooth stones, mounted in handles, as in figs. 398 to 401. The work is next trimmed at the back and edges, and then smoothed by pumice-stone properly shaped, the work being wetted from time to time. Much of the success of the burnished gilding depends upon having a good smooth foundation of whiting. The moulding is next dried, rubbed down with sand-paper, and then *gold-sized*, gold-size being a compound of pipe-clay, red chalk, black-lead, suet, and bullock's blood. This is laid on with a soft hog's-hair brush, or with a large camel's-hair pencil, from four to eight coats being used. The whole is next smoothed by washing with a soft sponge and water, and the parts which are to be *matt* or *dead* are polished with woollen cloth, while the parts to be burnished receive another coating of gold size. All is now ready for *gilding*, the tools for the purpose consisting of a *cushion* (fig. 414), covered with leather, with a parchment rim round a portion of its sides, to prevent the wind from blowing away the gold leaf; of a knife used for cutting gold (fig. 402), peculiar in shape, and of a tool used for laying on the gold, which is a kind of camel's-hair brush (fig. 406), called a *tip*. The gold is in leaves so thin, that upwards of 290,000 of them would be required to make up the thickness of an inch. These are contained between the leaves of a book (fig. 416), and the gilder, supporting the cushion on his left hand, by inserting his thumb through a leather loop underneath, and holding the tip, the knife, and the camel's-hair pencil between the fingers of the same hand, blows out the leaves of gold from the book on his cushion, and then taking up one leaf with his knife, he lays it down on the front part of the cushion, and spreads it out by gently blowing on it. Then taking his knife, he divides the leaf into a number of parts or *lays*, and, wetting a portion of the moulding with a camel's-hair pencil, he takes his tip in his right hand, lays it on the slip of gold which adheres slightly to the hairs, takes it up, and places it on the moulding, blows forcibly upon it to expel some of the water from below, and presses down any parts which do not adhere, by means of a dry camel's-hair pencil. In this way he proceeds until all the lays into which the moulding has been divided, have been covered. When properly dry, a flint or agate burnisher is passed over those parts which are to be burnished, and those parts which are not burnished are *weak-sized*, or wetted with water containing a small quantity of size. When dry, the gold is wiped with cotton wool, and faulty places are repaired with gold leaf, and the work is wetted with *finishing size*.

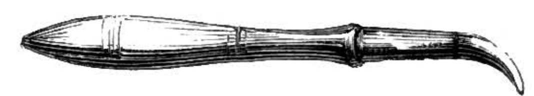
The frame-maker, who is distinct from the gilder, now takes the moulding and cuts it up into pieces of the required length, and makes these pieces up into a frame. In cutting up the moulding, the saw is guided by a *mitre-box*, which consists of two raised ledges of wood, with oblique cuts in them; the moulding is placed between these ledges, and a back-saw being introduced into the cuts, the moulding is accurately divided by oblique cuts, and these surfaces being smoothed by a plane, are fixed by means of glue and nails. Much skill is required to produce a frame, without soiling or injuring the gold. The gilder now takes the frame again, stops up the nail-holes with putty, paints the outside yellow, and, if any small light ornaments are required for the corners, attaches them already gilt by means of weak glue. In gilding a richly-ornamented frame, the processes vary somewhat, but the above description will sufficiently indicate the nature of the gilder's work.


397. PUTTY KNIFE.

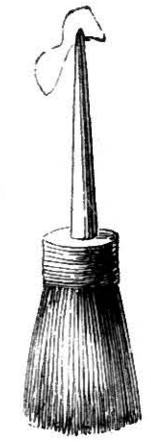

398. MINIATURE BURNISHER.


399. BURNISHER. No. 1.


400. BURNISHER. No. 2.


401. BURNISHER. No. 3.


395. BADGER TOOL.

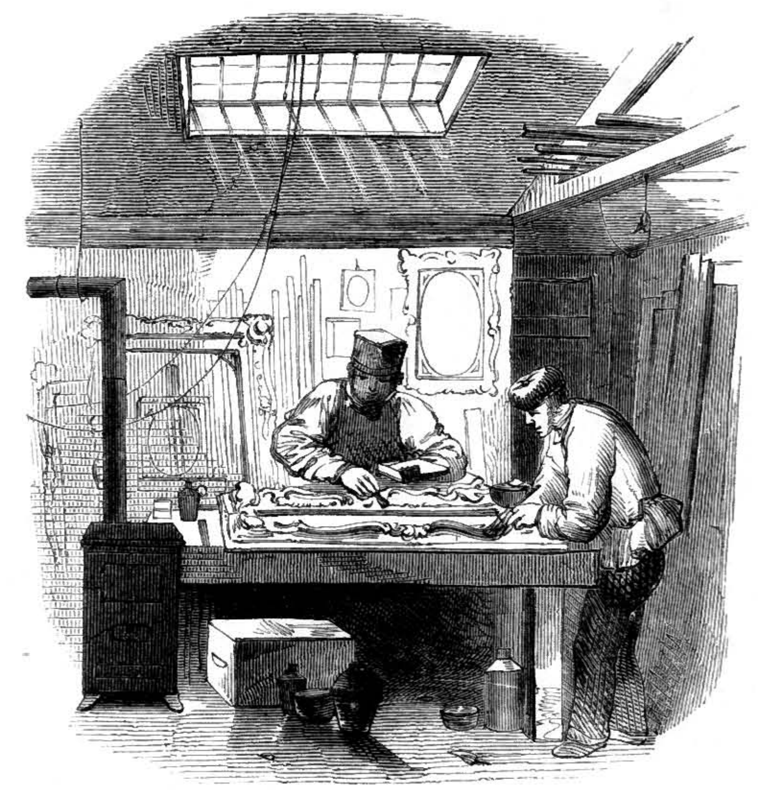

396. DUSTER.


402. KNIFE.


403. SKEWING BRUSH.


404. PUTTER-DOWN.

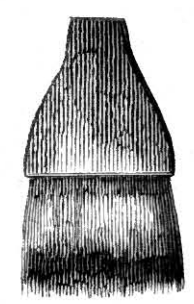

405. SIZE POT.

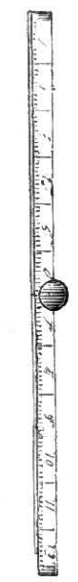

408. WORKSHOP.


409. FEATHER DUSTER.


410. GOLD SIZE POT.

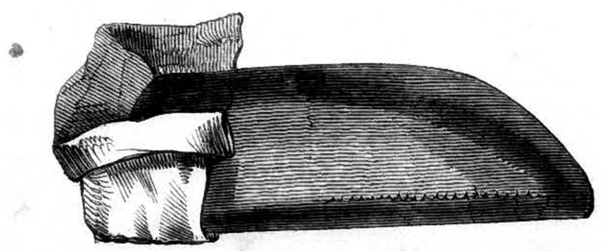

411. SIZE.


406. TIP.


407. RULE.

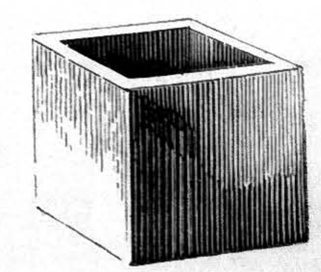

412. WHITING.


413. PIPKIN.

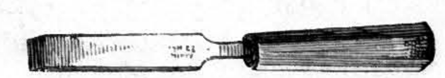

414. CUSHION.


415. PAN.


416. GOLD BOOK.


419. GOLD LEAF BOX.


417. SMALL PENCIL.


418. CHISEL.

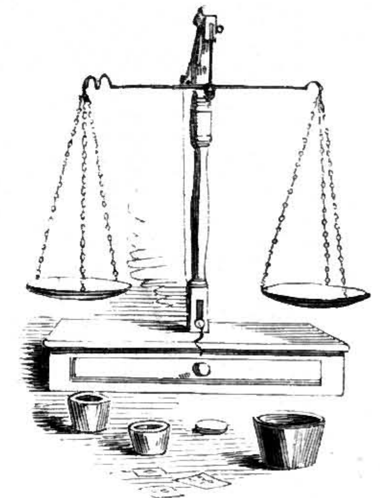
XX.—THE GOLDBEATER.

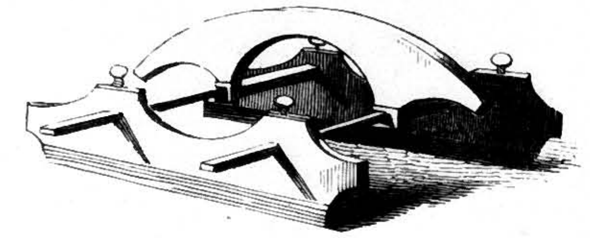
The preparation of the gold leaf, as used by the gilder, is the business of the goldbeater, who, taking advantage of the wonderful malleability or powers of extension possessed by the precious metal, beats it out into such thin leaves that 290,000 of them would be required to make up the thickness of an inch. That such is the case may be proved by a little calculation. A cube of gold, weighing one ounce, would measure on each of its sides five-twelfths of an inch, and would cover a space of little more than one-sixth of a square inch. Now the goldbeater hammers out this cube of gold until it covers 146 square feet, and, in order to extend it from a surface of five-twelfths of an inch square to one of 146 square feet, its thickness must be reduced from five-twelfths of an inch to the 290,636th part of an inch. Gold is often beaten much thinner than this; even to the 367,650th of an inch, or about 1,200 times thinner than ordinary printing paper; but this is not the limit of malleability, although there are practical difficulties in the way of further reduction.

The goldbeater uses pure gold mixed with various proportions of silver or copper, to obtain different *colours*, as he calls them; and of these there are about thirteen, namely: *fine gold, red, pale red, extra deep, deep, orange, lemon, deep pale gold, pale, pale pale, deep party, party,* and *white.* The deeper colours are alloyed with copper, the middle colours with silver and copper, and the paler golds with silver only. The metals are fused together in a crucible, and cast into a flat, oblong ingot, one and a half inch long, three quarters of an inch wide, and three-sixteenths of an inch thick. This ingot is flattened out into a ribbon by being passed repeatedly between two rollers of polished steel, until it is spread out to a surface of 960 square inches of the thickness of rather more than $\frac{1}{800}$th of an inch. The ribbon is annealed or softened by means of heat, and is carefully marked out by compasses (fig. 422) into square inches; and 150 of these are placed between leaves of a tough paper of peculiar make, the packet of which, called a *cutch* (fig. 429), is enclosed in a parchment case open at both ends, and this in a second case, so as to cover the edges left exposed by the first. The packet is then beaten for 20 minutes with a 17-lb. hammer (fig. 424), on a smooth block of marble well supported from below, and surrounded on three sides by a raised ledge of oak: the front edge, which is open, is furnished with a leathern apron for catching any fragments of gold that may escape in the after operations. The cutch is so elastic that the hammer bounds off from it, and lightens the labour of the beater, who turns the packet over from time to time, to equalize the force, and occasionally bends it to and fro, to prevent the gold from sticking to the paper. The packet is also opened from time to time, for the purpose of re-arranging the squares of gold, and the beating is continued until the one-inch squares are spread out into four-inch squares. The packet is now opened, and being held at one corner by the *span-tongs* (fig. 428), each piece of gold is removed, placed on a cushion, and cut into four pieces by means of a knife (fig. 434). In this way the 150 pieces become 600, and these are put between the leaves of a *tool*, made of goldbeaters' skin, called a *shoder*. This is enclosed in parchment cases, and beaten for 2 hours with a 9-lb. hammer (fig. 425), until the squares of gold are spread out nearly to the size of the skin, when the leaves of gold are again divided into four, and each quarter is placed between two membranes. The gold is now divided by means of the smooth edge of a strip of cane (fig. 437), since it has a tendency to adhere to a knife. The squares of gold, now 2,400 in number, are separated into three parcels of 800 each, and each parcel is made up in what is called a *mould* of goldbeaters' skin and beaten as before, when the squares again expand nearly to the size of the skin, and the process of beating is considered at an end. This last beating requires skill. During the first hour the hammer is directed chiefly on the centre of the mould. This causes the edges of the leaves to crack, but they unite again when beaten. During the second hour, when the gold is the 150,000th of an inch in thickness, it allows the light to pass through. If the gold be pure, or but slightly alloyed, the transmitted light is of a green colour; but pale violet if highly alloyed with silver. The mould is beaten during 4 hours with a 7-lb. hammer. The thin leaves are then taken up, one at a time, by means of wooden pincers (fig. 436), placed on a cushion, and blown out flat by the mouth. The ragged edges are cut off by means of the tool (fig. 421), called a *waggon*, consisting of edges of cane mounted in a frame, the sides of which are $3\frac{1}{4}$ inches apart; there is a handle in the middle. In this way the dimensions of the leaves are reduced to about three and a quarter inches square. Twenty-five leaves are placed between the folds of a paper-book (fig. 439), the surfaces of which have been previously rubbed with red chalk to prevent the gold from adhering. As the book is being filled a leaden weight is kept at one corner of the filled portion to prevent the leaves from being blown up, and as the books are filled they are placed in a pile with the weight (fig. 423) upon them.

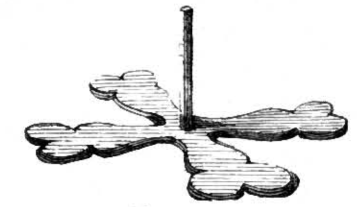
Steam machinery has been proposed and partially introduced for goldbeating, but this, we are told, has proved a failure. Silver and copper-leaf are prepared somewhat after the same manner as gold-leaf. Copper is much less malleable than gold, and silver-leaf is thicker on account of the less density of the metal; but calculated by weight, it does not appear that gold is more malleable than silver. The silver-leaf, however, which is used for silvering letters on omnibuses, &c., is really gold largely alloyed with silver. Pure silver-leaf would be liable to tarnish. There are other metals, such as platinum, palladium, aluminium, lead, zinc, cadmium, and tin, which admit of being beaten out into thin leaves. What is called *dentists' gold*, or the gold used for stopping teeth, is the gold beaten out from the ingot, then divided, and beaten out once again.

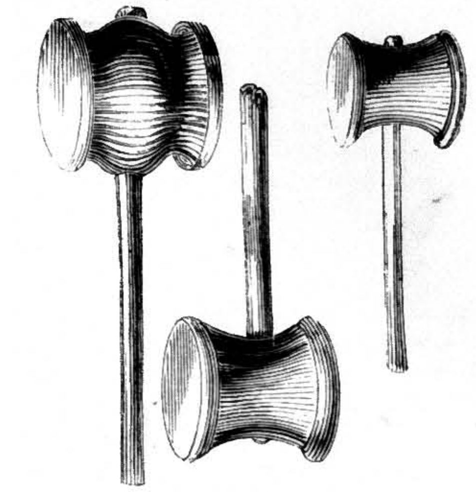
What is called *goldbeaters' skin* is the serous membrane separated from the intestinal tube of the ox, and sometimes of other animals: it is spread out in the frame (fig. 443, see also fig. 431), scoured with pumice (fig. 432), made thin by being beaten with a hammer, and prepared with solutions of alum, isinglass, white of egg, &c. so as to resist putrefaction. A mould of skins contains 850 leaves, $5\frac{1}{2}$ inches square (each leaf being double), and nine-sixteenths of an inch thick, to produce which requires the slaughter of 500 oxen. A mould of skins costs £10, but it may be used during several months; and when the leaves are too thin or too weak for use, their flexibility may be restored by placing them between leaves of white paper, moistening them with vinegar, loading them with weights, and leaving them for a few hours. They are then beaten for a number of hours between leaves of paper or parchment, after which, to prevent the adhesion of the gold to the surface of the skin, they are rubbed over with calcined fibrous gypsum in powder, and are again fit for use. The powder is called *brime;* it is passed through the *sieve* (fig. 427), and is rubbed on with the *hare's-foot* (fig. 438). The dryness of the cutch, shoder, and mould are of importance; to insure which, they are hot-pressed in the iron *press* (fig. 433), every time they are used. In frosty weather the tools may become over dry, and then the lustre of the gold becomes dimmed and spreads slowly under the hammer. If the cutch or shoder be damp, the gold will become *hollow*, or *sieve-like;* that is, it will be pierced with numerous microscopic holes, and in the moulds will pass into a pulverulent state. The *rasp-knife* (fig. 441) is used for trimming the edges of the mould. The waste fragments of gold and the cuttings of the leaves are melted down into a globule of gold.

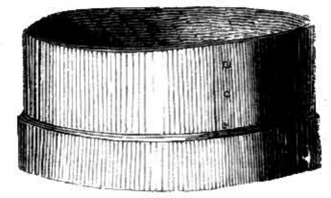

420. BALANCE.

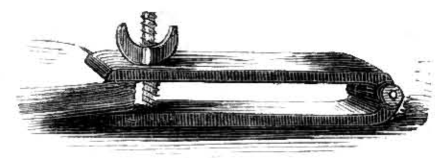

421. WAGGO .

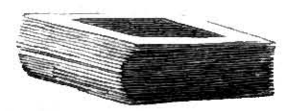

422. COMPASSES.


423. CROSS LEAD.


424, 425, 426. CUTCH, SHODER, AND MOULD HAMMERS.


427. SIEVE.

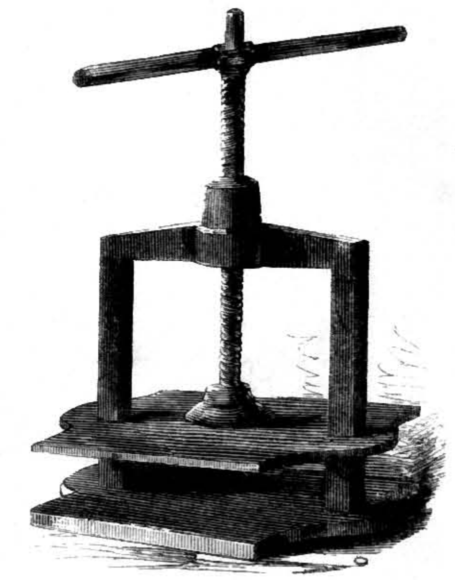

428. SPAN TONGS.

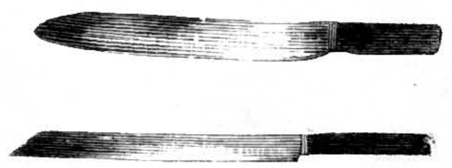

429. CUTCH.


430. MOULD.

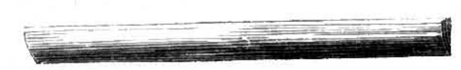

431. FILLING FRAMES.


432. PUMICING.


433. PRESS.


434, 435. SKEWING KNIVES.


436. PINCERS.

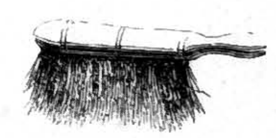

437. REED.

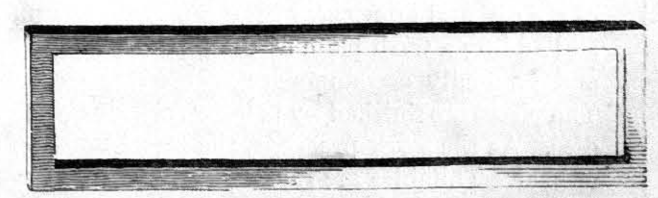

438. HARE'S FOOT.


439. GOLD LEAF BOOK.


440. GOLDBEATERS AT WORK.


441. RASP.


442. BRUSH.


443. FRAME.

XXI.—THE GOLD AND SILVER SMITH.

It is interesting to observe how well the processes of the Useful Arts are adapted to the nature and properties of the materials which are to be operated on. The ductility and malleability of many of the metals allow of their being wrought into a variety of beautiful and useful forms, such as deep vessels in common use, without any seam or join. In this way are formed tea-pots, coffee-pots, covers of cups and vessels, extinguishers, thimbles, the bell-mouths of certain musical instruments, &c. There are three methods adopted by the gold and silver smith for producing such articles. The first is called *spinning*, or *burnishing to form*, and is performed rapidly at a lathe. The second is *raising* by means of a hammer; and the third is *pressing* between dies. As an example of spinning, we may describe the method of forming the body of a tea-pot out of a flat disk of metal. The disk *d d* (fig. 448) is held by the fixed centre screw *s*, of the lathe, between two flat surfaces of wood *w w*, one of which, *m*, has the form of the lower part of a tea-pot. Now, it will be evident that as the lathe spins round, the mould *m*, the disk *d d*, and the piece of wood *w*, would all revolve with it. The workman now takes a burnisher *b*, and resting it against a pin in the lathe-rest, applies it to the metal near the centre, while at the opposite side is held a wooden rod *r*, to support the edge. In this way, the metal is rapidly bent or suaged into the form No. 2, and then into Nos. 3 and 4, so as to fit upon the block *m*. The latter is now removed, and its place is supplied by a smaller block *c*, of the same size as the mouth of the intended tea-pot. A burnisher, with its surface slightly greased, is used, together with a hooked stick *h*, for forcing the metal gradually inwards to the forms shown at 5, 6, 7, and also for curling up the hollow bead which stiffens the mouth of the finished vessel, No. 9. In some cases, the mould is of the shape of the finished vessel, and can be taken to pieces in order to be removed.

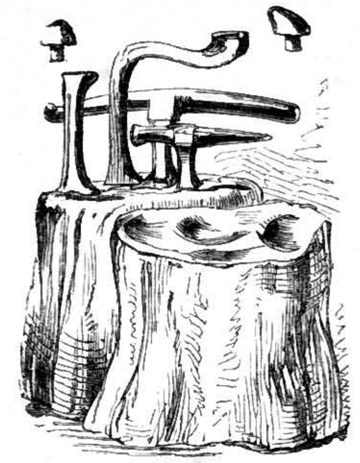
In raising by means of the hammer, the blows are applied in circles, much in the same manner as the burnisher in spinning, so as to produce the effect by gradual and continued pressure. The metal disk must be of such a size and thickness as to produce the intended article by raising, without leaving any excess of metal to be cut off, or any deficiency to be supplied, and the blows of the hammer must be so managed as to give the finished work the same thickness throughout. Such works as jelly moulds, where the raising is considerable, are done by the hammer; but works in less relief, and required in considerable numbers, are produced by means of dies. But here the work must be gradual, or the metal will be cut and rent. The method of arranging the dies is shown in figs. 447, 455, and the method of working has already been described in our *Illustrations of Manufactures* (figs. 499, 511, 513, &c.). The raising by means of dies must also be gradually brought about, and this is done by placing a number of sheets of metal between the two parts of the die, and after every blow removing one piece from the bottom, and adding a fresh plate at the top. In this way, the plates descend and gradually accommodate themselves to the figure of the die. The pieces are finished by being struck singly between corresponding dies. As the work proceeds, the metal must be annealed by means of heat. Thimbles are raised in five or six blows, between as many pairs of conical dies, which gradually increase in height.

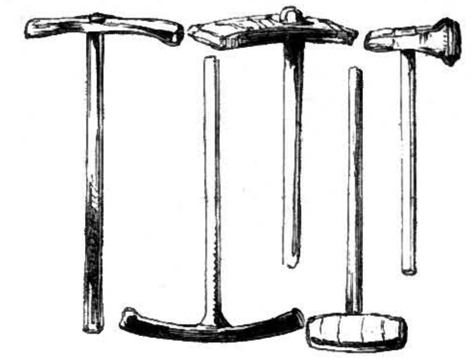
A number of ornamental details, such as escutcheons, concave and convex flutings, &c., are added to the vessel after it has been raised. An ingenious method of executing this part of the work is by means of a *snarling-iron*, *s* fig. 449, one end of which is secured in a vice *v*, and the other end *e* is turned up so as to reach any part of the inside of the vessel. The work is held firmly in the hands with the part to be raised or set out over the end *e*, when the snarling-iron is struck by an assistant with a hammer, and the reaction gives a blow within the vessel, the effect of which is to throw out the metal in the form of the end of the tool. When the ornaments have been snarled up, the vessel is filled with a melted composition of pitch and brick-dust, to serve as a support in the operation of *chasing* (fig. 450), and leave both hands of the workman at liberty. The work is then gone over with a punch *t* and a hammer, or with one of the gravers shown in fig. 446. The punches, or chasing tools, are usually counterpart forms of the snarled up parts, and with these the work is corrected and made uniform.

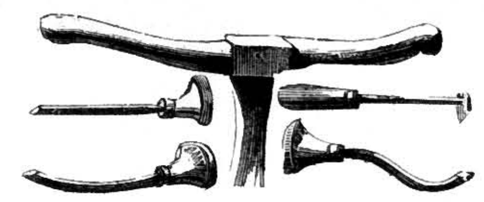
The gold and silver smith uses various forms of hammer (figs. 445 and 451), and irons of different shapes (figs. 444, 451, 453). The furnace for melting his metals and alloys (fig. 458) resembles the brass furnace described in the *Illustrations of Manufactures*, fig. 494. The polishing of silversmiths' work is done first with pumice-stone and water, then with Ayr-stone and water; thirdly, with a revolving brush with rotten-stone and oil (fig. 457); next with an old black worsted stocking with oil and rotten-stone, and it is finished with the naked hand, an operation in which women succeed better than men. But there is considerable difference even among women, a peculiar texture and condition of the skin being required for the purpose. The deep black lustre of silver is given by means of very fine rouge applied with the hand, for which purpose the skin should be soft and slightly moist, so that the powder may become attached to the hand, and there may be a certain amount of adhesion between the hand and the work. A dry hand becomes hard and horny, and is apt to scratch the work, and a very moist hand becomes too slippery. The corners and edges of the work are usually burnished with a steel burnisher moistened with soap and water.

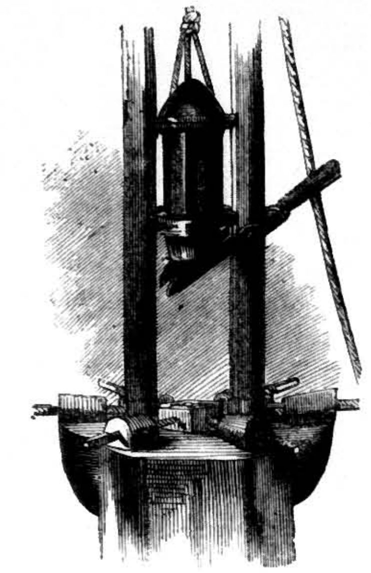
Some kinds of silversmiths' work are pierced and finished with the graver. The pattern is first drawn upon the article, pierced with a breast drill, and then cut out with a piercing saw, which is a fine frame saw, tightened somewhat after the manner of a violin bow.

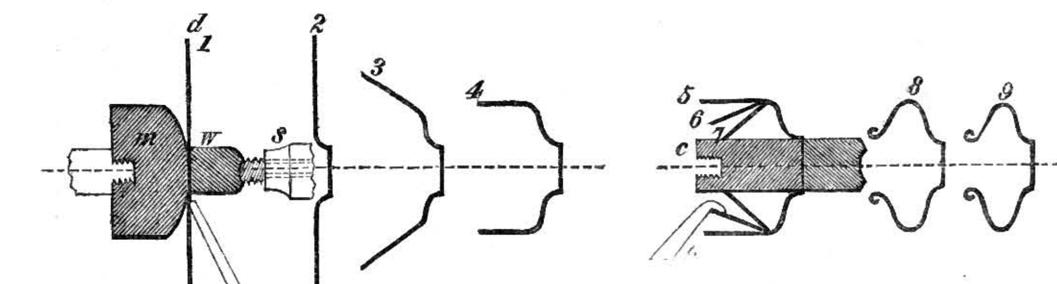
Gold plate is made of gold more or less alloyed with silver and copper. The purity of gold is expressed by the terms 22, 18, 16 *carats*. The pound troy is supposed to be divided into 24 parts; and could gold be obtained absolutely pure, it would be called 24 *carats fine*. The *old standard gold* of our currency is called *fine*, and consists of 22 parts gold and 2 of copper. The *new standard* for watch cases, &c. is 18 carats fine gold, and 6 of alloy. Gold inferior to 18 carats is rejected at Goldsmiths' Hall. It is then described by its commercial value, as 60 or 40 *shilling* gold, &c. The alloy may be of silver, which gives a green colour, or entirely of copper for a red colour, but the two metals are usually mixed.

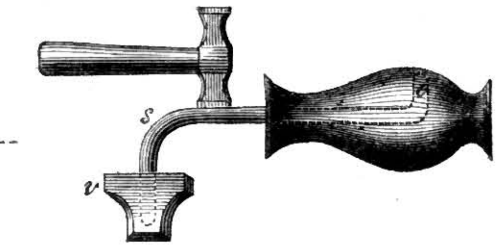

444. BLOCKING BLOCK AND HORSES.

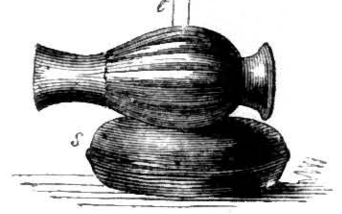

445. HAMMERS.


446. GRAVERS AND HORSE.


447. THE DROP DOWN.

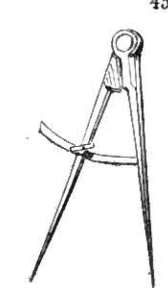

448. SPINNING OR BURNISHING TO FORM.

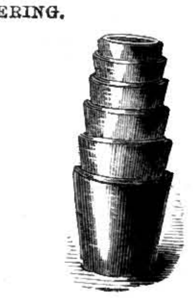

449. SNARLING UP.

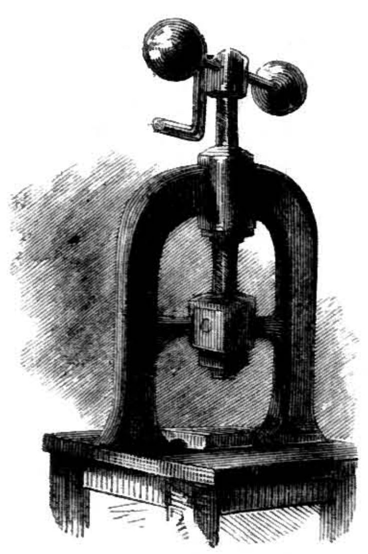

450. CHASING.

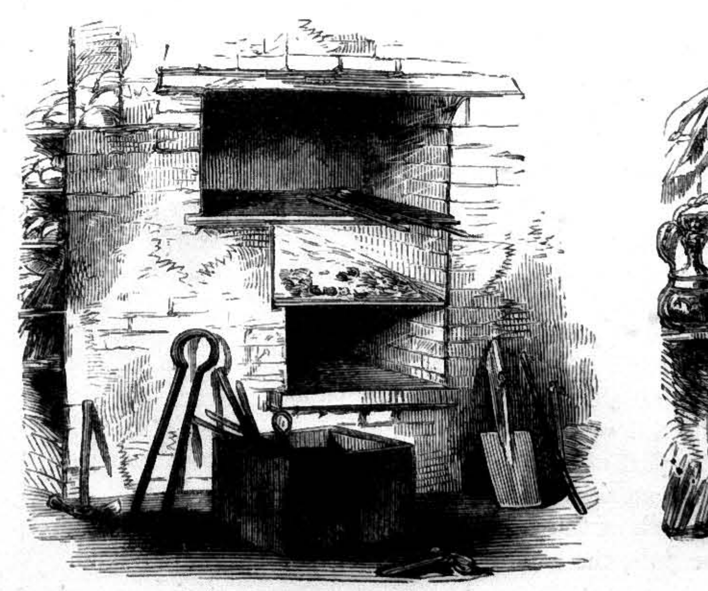

451. ANVIL, DIES, SLEDGE HAMMER.


452. HAMMERING.

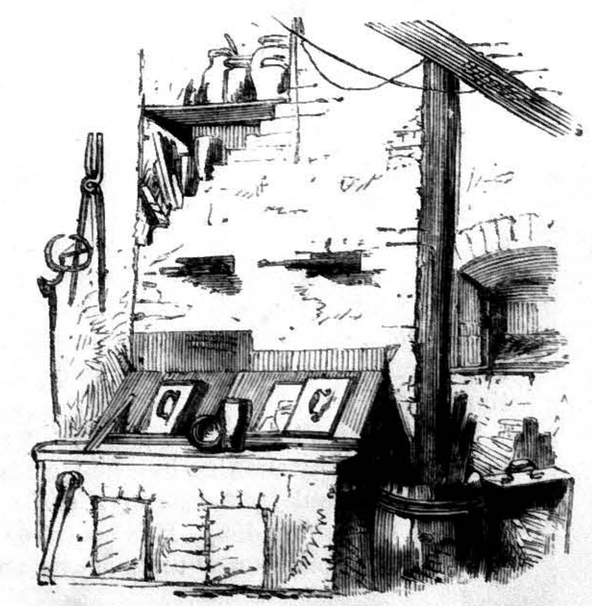

453. CALLIPERS.


454. TRIPLETS.


455. FORK PRESS.


456. FORGE AND IRONS.


457. POLISHING.


458. FURNACES.

XXII.—THE TINMAN.

The manufacture of tin-plate was described in our *Illustrations of Manufactures* (fig. 512), and it was there explained that the term is a contraction for *tinned-iron plate.* The very thin coating of tin preserves the iron from rust, while the tin itself is the most wholesome and cleanly of metals. It is from this tin-plate that the tinman manufactures the pots, the kettles, the saucepans, the candlesticks, &c. which are so largely used in every household. He receives the tin in sheets, measures it with a rule, marks it with compasses or with a point, and cuts out the various pieces by means of *shears* (fig. 471) or *snips* (fig. 476). He is furnished with *anvils* (fig. 466), for planishing or making quite flat the pieces of plate before they are joined together, which he does by means of the *mallet* (fig. 478). He also has several kinds of anvil known as *stakes* and *teests* (figs. 466, 479), for giving angles or proper curves to the tin-plate. He also has a number of irons, such as the *crease iron* (fig. 459), for making small beads and tubes and also for creasing up, and thereby strengthening the edges of articles, a *funnel-stake* (fig. 461) for curving the tin-plate, a *horse* (fig. 463) mounted in a wooden block, or let into a square hole in the bench (fig. 470), and adapted to the holding of various swage tools; a *pudding-stake* (fig. 465), also mounted in a wooden block for moulding the surfaces of plates. Then there are *bick* or *beak-irons* (fig. 475), for passing into the interior of vessels, while a part of the exterior is being worked, and also for making long pipes. The tinman also has a variety of *punches* (figs. 462, 462*, 474), for making holes in the plate, for setting the heads of rivets, and some of the punches are made like *swage tools, top and bottom tools* or *creases* for making different mouldings and bosses. *Cutting punches* are used with a thin plate of lead or solder laid upon the stake, and on which the sheet to be cut or punched is placed, and also *chisels* and *seamsets* (fig. 464) for cutting notches and closing the seams prepared on one of the stakes. All these operations are sufficiently intelligible without any special description. We therefore pass on to notice the method of joining or *soldering* the various cut pieces of tin-plate, so as to form a finished article.

The solder or cement used in joining the different parts of works in tinned iron, is called *soft-solder*, and usually consists of two parts tin and one part lead. It is made into a lump or *pile* (fig. 477) and is applied by means of a copper *bit* or *bolt* (fig. 473), misnamed a *soldering-iron*, probably from the circumstance of the copper being riveted into an iron shank; it is fitted with a wooden handle. Before the bit can be used, it must be tinned, for which purpose it is heated in a small charcoal stove (fig. 472) to a dull red, quickly filed clean, then rubbed upon a lump of sal-ammoniac, and next upon a metal plate containing a few drops of solder, by which means the tool is coated; it is then wiped with a piece of tow and is ready for use. The edges of the work having been brought together are strewed with powdered resin, and the bit being held in the right hand and the cake of solder in the left, a few drops of the latter are melted along the joint at short intervals. The hot soldering-iron is then made to heat the edges of the metal, and to fuse and distribute the solder along the joint. Two soldering tools are generally in use, the one in the stove, and the other in the hand. The bit must be hot enough to raise the edges to the melting point of the solder, and not too hot to burn off the coating. The bit is intended to act both as a heating tool and as a brush; to pick up small quantities of solder from the pile, and then to distribute them along the edge of the joint. A skilful workman will make a fine and regular line of solder; and he cools the part just finished by blowing upon it. For the best tin wares, muriate of zinc is used instead of resin, and with this the joint is moistened by means of a small wire or stick, before the application of the hot tool.

The tinman often works in sheet zinc as well as tin-plate; this is more difficult to solder and does not make so neat a joint, since the zinc is apt to remove the tin coating from the soldering tool. Muriate of zinc or sal-ammoniac is used as the flux.

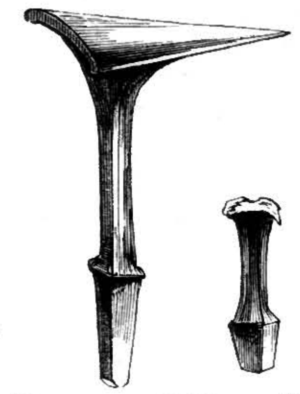
XXIII.—THE SURVEYOR.

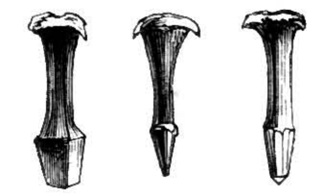
The surveyor is accustomed to call his employment a *profession* rather than a *trade*, and the distinction is a just one, seeing that every one of his employments requires a special adaptation of intellectual exertion, whereas a trade depends chiefly on skill of hand, which, once acquired, can be exercised almost without thought, and one article is but a copy of the one just finished, and a model for the one that is to succeed it. We think it right, however, to say a few words about the surveyor's employments, preparatory to a notice of the work of the road-maker, the bridge-builder, and the canal and railway engineer; for it is the surveyor who lays out the ground, determines the levels, and marks the most convenient line of route, such as will be the most economical in the making, and the most profitable in the working. The surveyor does all this in addition to his employment of measuring fields, mapping out estates, valuing timber, &c.

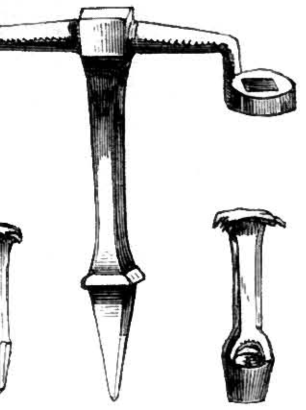
The best idea that we can give of the surveyor's work within our brief limits, is by showing how he measures a field. In this country land is measured by means of a chain called, after its inventor, *Gunter's Chain* (fig. 489). It is contrived so as to simplify computation, as far as our clumsy units of area and length will admit. The smallest of the three units of area used for land is the *perch*, and this is the square of one of our units of length, namely the *rod* or *pole*; but the two higher measures, the *rood* and the *acre*, correspond to the squares of no lineal measure. The reader will understand why we speak of squares, from the simple method of ascertaining the area of a given space. We have only to multiply the length by the breadth to get the area in square feet, square yards, &c. Thus, a room measuring 12 feet in its length, and 12 feet in its breadth, has for its area 144 square feet, because $12 \times 12 = 144$, while another room, measuring 6 yards long and 3 yards wide, evidently contains 18 square yards. It happens, however, that the acre is $\frac{1}{10}$th of a square furlong, so that when disposed in a strip 1 furlong in length, it is $\frac{1}{10}$th of a furlong wide, and it was this that determined the most convenient length of the chain, as containing exact though awkward numbers of all the smaller units, namely, 4 *rods* or *poles* = 22 *yards* = 66 *feet* = 792 *inches*. The length of the chain thus becomes the 80th part of a mile, or the 10th of a furlong, and its square the 10th of an acre; $2\frac{1}{2}$ such squares make 1 *rood* or $\frac{1}{4}$th of an acre, and the 40th of this, or the square of a $\frac{1}{4}$ chain, is a *perch*, or square *rod* or *pole*, the smallest unit used for cultivated land.


459. CREASE IRON.

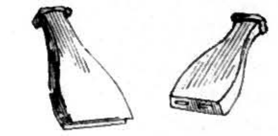

460. BLOCK HAMMER.


461. FUNNEL STAKE.


462. PUNCHES.

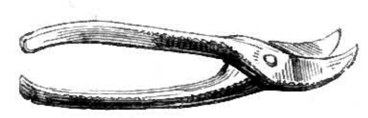

463. HORSE.

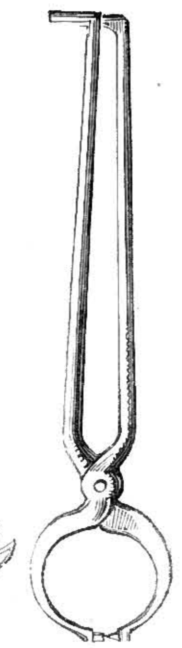

462*. PUNCHES.


464. CHISELS.

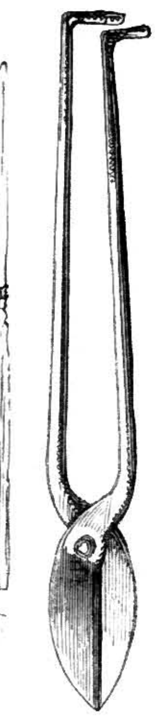

465. PUDDING STAKE.

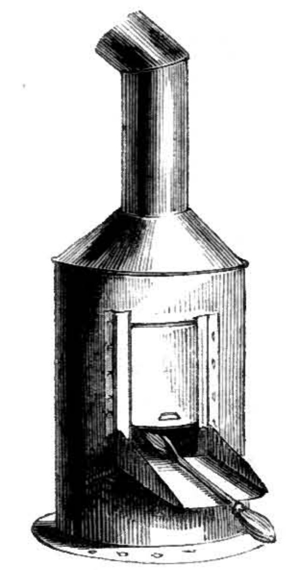

466. POLISHING ANVIL.

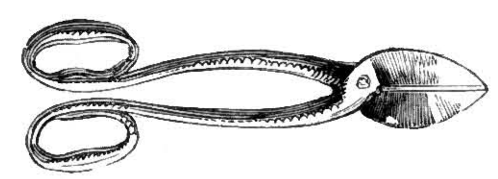

467. BENT SNIPS.


468. TONGS.

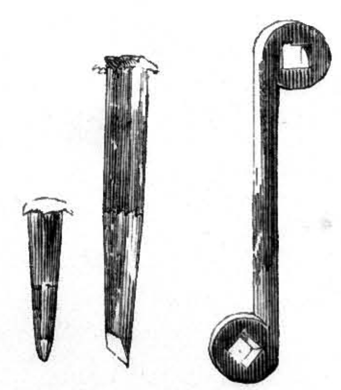

470. WORKSHOP.

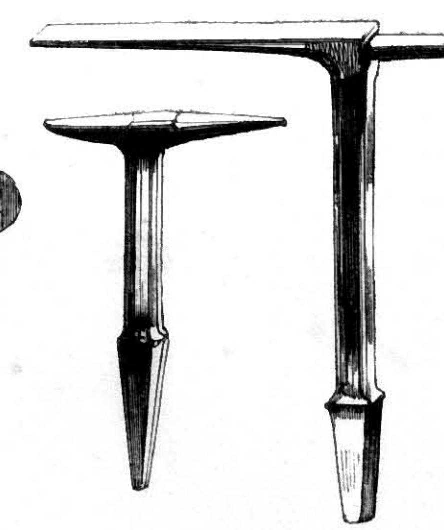

471. LARGE SHEARS.

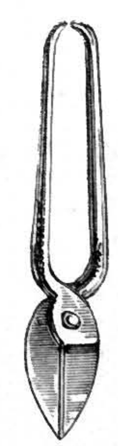

472. CHARCOAL STOVE.

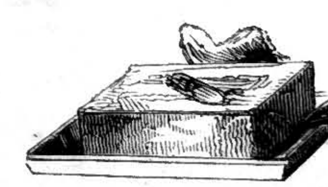

469. SCOTCH SNIPS.

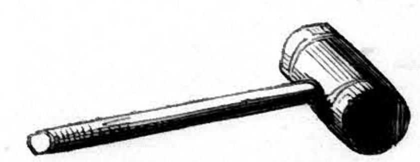

473. SOLDERING IRON.

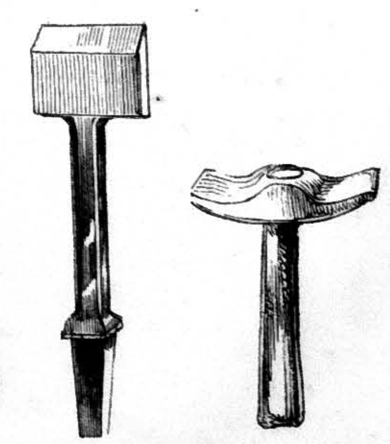

474. PUNCHES AND TWO-HANDED WRENCH.


475. BICK IRONS.


476. STRAIGHT SNIPS.


477. SOLDERING PILE.


478. MALLET.


479. HATCHET STAKE AND HAMMER.

The division of the chain into feet would make the calculation too complicated, by introducing fractions, since the pole is $16\frac{1}{2}$ feet. Some chains, however, when used for measuring distances, consist of only 132 half-foot links; but the usual chain has 100 links, so that the measurements may all be expressed in links, and by simply omitting the last two figures the number of chains' length is at once seen. Thus, 2135 links = 21 chains 35 links, and as all calculations of area lead to a result in square links, which are ten-thousandths of a square chain, or hundred-thousandths of an acre, they show at once, by omitting the last 5 figures, the acres, and by multiplying the 5 figures thus cut off by 4, and cutting off the last 5 figures from the product, the odd roods are shown, and by again multiplying the 5 cut off figures by 4, and cutting off the last 4 of the product, we get the odd perches, and the 4 cut off are decimal parts of perches. The link measures 7·92 inches, but neither inches nor feet are used on account of the decimal parts. Between every two links are one, two, or three small rings for the purpose of giving flexibility to the chain. When the chain is required for rough work it is made to consist of 200 half-links, instead of 100 whole ones, to prevent the risk of bending. In order to distinguish the middle of the chain a round piece of brass is introduced, and the 40th link from each end is marked by a 4-fingered bit, the 30th by a triple, the 20th by a double, and the 10th by a single finger; there is also a mark at the 25th link, which renders the counting of odd poles or links a quick operation. The chain has a handle at each end, and the man who pulls the chain is directed by him who follows to place a pin in the straight line with the mark towards which they are proceeding; or in continuing a previous line the leader can himself insert the pin. He has at starting ten of these pins, which the follower picks up as they are left, so that at the end of every furlong they must be given back to him, and an entry of 1,000 be made in the fieldbook.

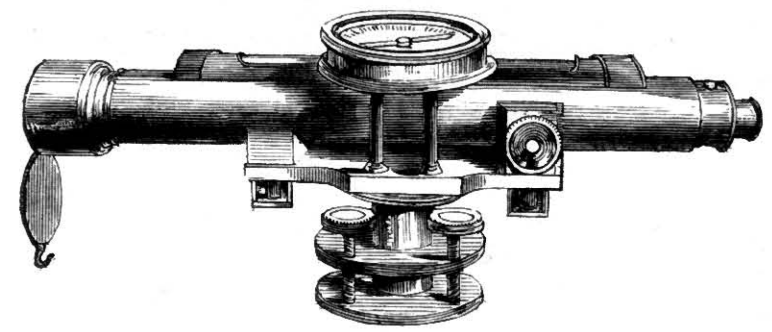
In surveying a single inclosure with 4 straight sides, such as fig. 497, each side is measured, and one diagonal such as *A B*. On transferring these five dimensions to paper, which is called *plotting*, and dropping a perpendicular to the diagonal *A B* from each of the other angles, and measuring them by the *plotting-scale*, which will be found in the box of instruments (fig. 500), we multiply half the sum of these perpendiculars by *A B*, which gives the area of the two triangles of which the common base is *A B*; or, in other words, we get the area of the whole field. In this way any figure with straight sides, however complex, can be divided into triangles, less in number than the sides by two, and every side of each triangle being measured in the field, their perpendiculars can be measured on paper. For a curved boundary the surveyor measures a straight line as near it as convenient, and makes this line a side of one of the triangles, and while measuring it he takes also a series of distances from different points of it to the curve. These are called *offsets;* they must be perpendicular to the straight line, and are usually measured with rods (fig. 488), placed against the chain without disturbing it. In this way means are furnished for plotting as many points of the curve as there are offsets, and through these points the map may be drawn (fig. 501). The area of each space between two offsets is taken as if the boundary line joining their ends were straight, and this area is found by multiplying the half sum of the two offsets by their interval. The whole offset space must be added or subtracted according as it lies within or without the triangulation of the field. If the surveyor has merely to compute the area, he has no occasion to sketch any map at all, for by proper entries in his fieldbook he has all that is necessary for the computation.

In addition to the chain, the surveyor usually has some instrument for finding the spot in any line from which a perpendicular thereto will reach a given distant point. In this way a good deal of measurement is saved; as for example, in fig. 497, the only use of chaining *A B*, *C B*, is to define the place of *C*, whereas, could we know in the field on what point *D* of the chained line *A B* a perpendicular to it from *C* would fall, we should only have to measure this perpendicular, instead of the two lines *A C*, *C B*, both longer than *C D*. In this way 3 lines instead of 5 would suffice to plot and survey the whole field, and the perpendiculars could be better measured on the field than in a paper plan. The oldest instrument used for this purpose is the *cross staff*, consisting of a piece of board for a head, with two deep saw-cuts in it at right angles. This being mounted on a staff, and planted in some part of *A B*, and turned round so that through one of its grooves *A* can be seen in one direction, and *B* in the other, the observer will see through the other groove to the right or left of *C*, and he must move the staff along *A B* until it is placed on a spot which will admit of the three marks *A*, *B*, and *C* being seen through the two grooves. The cross staff has been superseded by the optical square, which consists of two pieces of looking-glass fixed in a box, and inclined 45° to each other. Half the silvering of one glass is removed, and the eye, directed to it, can see an object directly in front through the transparent portion, and another object reflected from the other glass to this one, and thence to the eye, so that the latter object must be 90° distant from the former, and by walking along the part of *A B* where we expect the perpendicular to fall, with the instrument at our eye, and *A* in sight through it, various objects about *C* will appear reflected in succession; and when the image of *C* itself coincides with *A*, we are at the right spot.

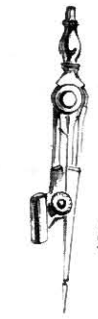
The instrument commonly used for measuring horizontal angles is the *theodolite* (fig. 491). In its simplest form it consists of a divided circle, which is to be set parallel with the horizon, and a telescope which moves in a vertical plane, so as to allow the observer to view any object which he may require above or below the horizon.

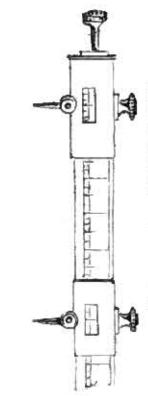
In laying out a line of road, railroad, or canal, the operation of *levelling* is required. Its object, as its name implies, is to ascertain the relative heights of points on the ground along the line of operation, for which purpose convenient stations are selected, and the distances between them ascertained. A kind of telescope called a *level* (fig. 481), is set up at or near the middle of the interval between two stations (fig. 480): it is made horizontal by means of adjusting screws, and an assistant at each station holding a station staff upright, as at fig. 482, moves a vane or index along it according to the directions of the surveyor at the telescope, until the index appears to coincide with the crossing of two wires fixed in the telescope. Having observed one staff in this way, the instrument is turned round without disturbing the stand, and the surveyor makes a similar observation and adjustment for the other staff. In this way proceeding along the line, and entering in a fieldbook the height of each staff from the ground up to the adjusted index in every case; entering one set of observations as *fore-sights*, and another set as *back-sights*, the difference between the sums of the numbers in the two columns will be equal to the height of one extremity of the line above the other.

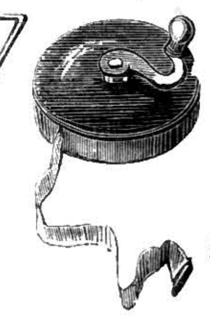

480. SURVEYOR.

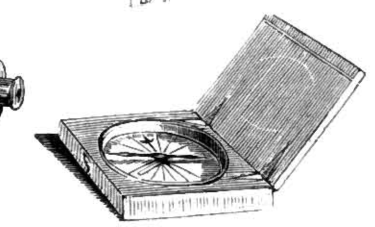

481. LEVEL.


482. ASSISTANT SURVEYOR.

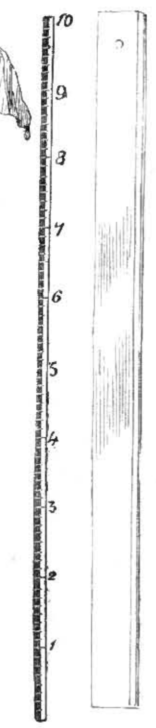

483. BOW PENCIL.

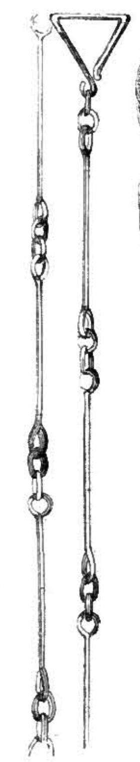

484. BEAM COMPASSES.


485. TAPE MEASURE.

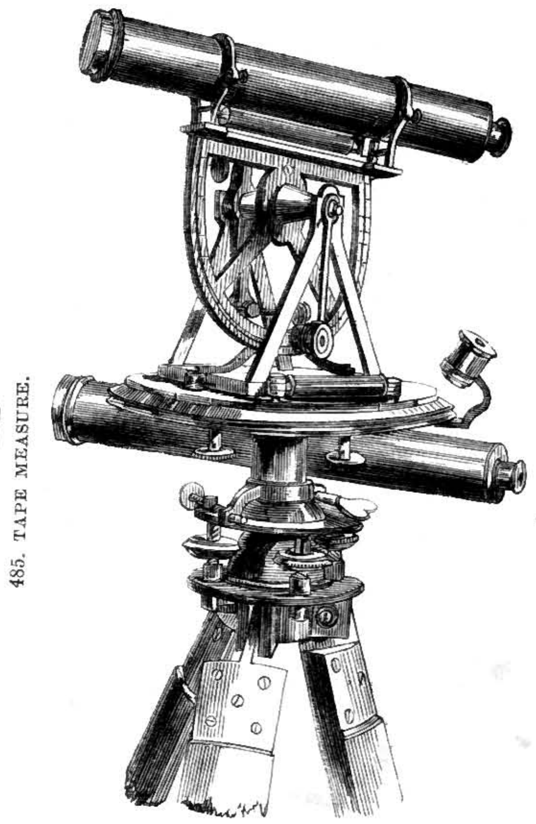

486. COMPASS.

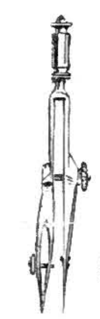

487. STAFF AND FLAG.


488. ROD AND STRAIGHT EDGE.


489. GUNTER'S CHAIN.

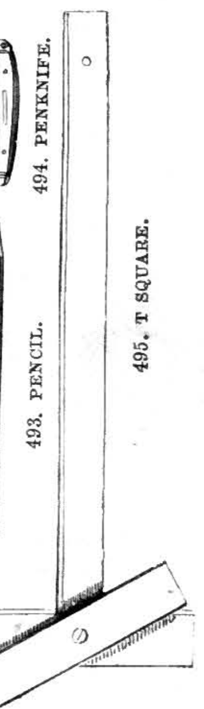

490. MATHEMATICAL PEN.

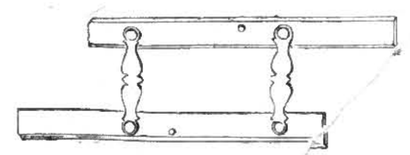

491. THEODOLITE.

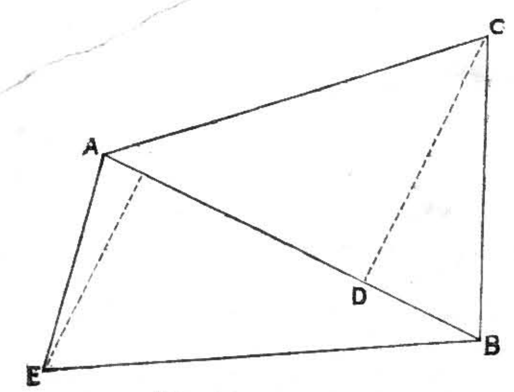

492. SPRING BOW PEN.

493. PENCIL.

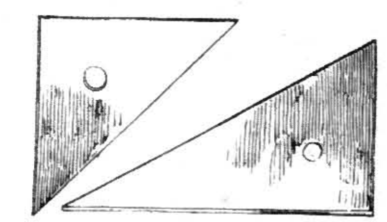

494. PENKNIFE.


495. T SQUARE.

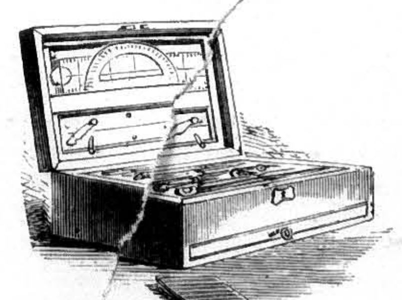

496. PARALLEL RULE.

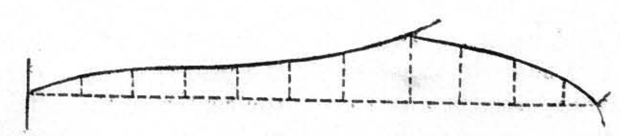


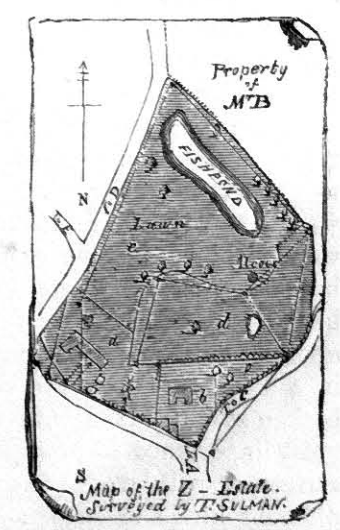
497. FOUR-SIDED FIELD.


498. SET SQUARES.


499. COMPASSES.


500. BOX OF INSTRUMENTS.


501. OFFSETS.


502. PLAN OF AN ESTATE.

XXIV.—THE ROAD-MAKER.

Few occupations are of more importance to a community than that of the road-maker. It has been well remarked that roads, canals, and navigable rivers may be considered as the veins and arteries through which all improvements flow. To internal trade and agriculture, they are as the veins and arteries of the human body through which the blood flows in every direction, and gives life, health, and vigour to the whole frame; but if the circulation be stopped in any one part, that part must suffer and react injuriously on the rest. So it is in a civilized country: without roads its otherwise most valuable productions have scarcely any value: its finest timber is often a source of inconvenience instead of wealth; its coals and metallic ores must lie undisturbed; agricultural produce benefits only the immediate producers of it; the sheep is killed for the sake of the fleece only; and above all man is separated from man, family from family, and the soothing and civilizing influences of intercourse with his fellows are greatly abridged.

The ancient Romans were our masters in the art of road-making. In every part of their vast empire they constructed roads, many of which still remain. They connected their different military stations by means of straight lines, skilfully overcoming natural obstacles by means of cuttings, embankments, bridges, and tunnels. Their first care was to secure a good foundation for the road, for which purpose they began, where necessary, by ramming the ground with smooth stones, fragments of brick, &c., and on this constructing a pavement of large stones firmly set in cement. Squared stones were occasionally used, and when irregular they were made to fit accurately. Basalt and the tough metal furnished by the primitive rocks were preferred, and if large stones could not be had, small ones were cemented together with lime, so as to form a kind of concrete to the depth of several feet. The road was generally raised above the level of the ground, and there were usually two carriage tracks with a raised footpath in the centre.

With such an enduring model before them, it might have been supposed that no doubt could have arisen as to the true principle of road-making; nevertheless, for many years the roads of Great Britain were constructed on two opposite principles: the first, that of Telford, who, following the Roman model, required the road to be laid down on a hard, solid, carefully prepared foundation; and the second that of M'Adam, who was indifferent whether the substratum were soft or hard, but of the two rather preferred the former. It is scarcely necessary to remark that Telford's method at length prevailed, and some of the finest roads of Great Britain were constructed under his immediate direction.

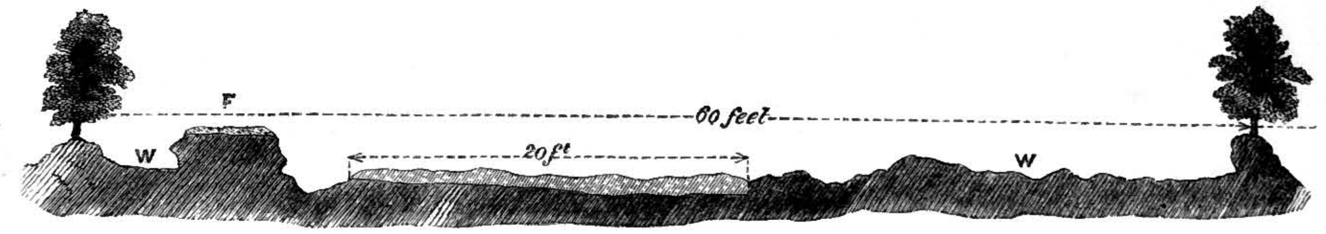
In laying out and surveying a line of road, a straight line is preserved, except when it is required to gain the proper rate of inclination without expensive cuttings or embankments. A convenient inclination, or *gradient* as it is called, is 1 in 35, and where the traffic is considerable, the width should not be less than 30 feet, exclusive of a footpath of 6 feet. The road should not be too convex, but the cross section should be formed of two straight lines inclined at the rate of 1 in 30, and united in the centre or crown of the road by a segment of a circle having a radius of about 90 feet.

In the great Holyhead road, Telford's foundation consisted of a rough, close-set pavement made of any common stone which the neighbourhood afforded. Where necessary, these bottom stones were laid with their broadest faces downwards, and the interstices were filled with stone chips, well driven in, to prevent the earth beneath from being pressed up and mixing with the coating of broken stones, and thus forming mud. When the coating is laid upon this well-prepared foundation, the stones soon wedge together in a solid uniform mass, vastly harder than a great thickness of broken stones mixed with the earth of the substratum. It is of great importance to produce this hardness and smoothness of the surface, as will be seen from the results of an experiment made on different kinds of roads:—A wagon was drawn on a well-made pavement with a force of 33 lbs.; on one of Telford's roads the power required was 46 lbs., on a road made with a thick coating of broken stone laid on earth 65 lbs., and on a gravel road also on earth 147 lbs.

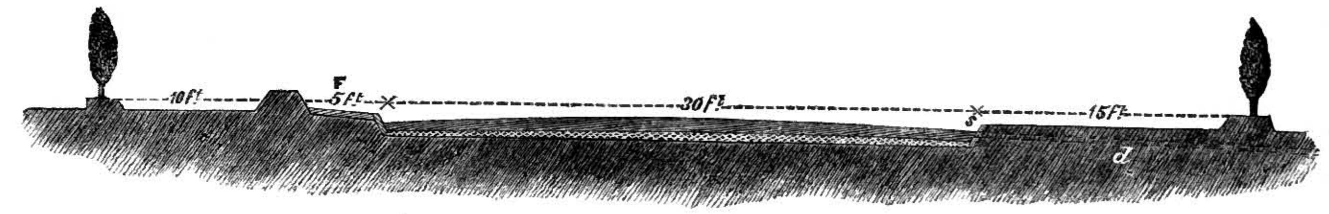
Figs. 503, 504, will serve to illustrate Telford's method of improving an old road. In the former figure, *W W* represent waste ground; in both figures *F* represents the footpath, and in the latter figure, *s s* the green sod, and *d* a pipe-drain. In fig. 506, the paved foundation with a layer of broken stones above it is represented at *B S*, the natural surface being shown at *NS*. *g* is the gravel footpath, *s* green sod, *dd* pipe-drains, *DD* main drains, *PP* posts. The transverse section of the road being gently convex will assist the drainage, and the ditch on each side should be sufficient to receive and carry off all the water that may fall on the road. The pipe-drains should be at distances of about 60 feet, and in cases where the substratum is a strong clay or a wet peat, trenches or drains must be formed across the road every 20 or 30 feet, each trench being about 4 inches square internally, formed of bricks or flat stones, as in fig. 509, the remainder of the trench being filled up with coarse stones. In districts where stone is scarce, but where lime and gravel are abundant, the foundation of the road may be formed of concrete.

M'Adam's method of forming a road of angular pieces of stone, without any kind of cement or binding material, is still adopted, whether on a hard foundation or not, and his name has been perpetuated in the verb to *macadamize*, which is applied to the process introduced by him. Tough hard stones should be used, and be broken to such a size as to pass freely through a ring $2\frac{1}{2}$ inches in diameter.

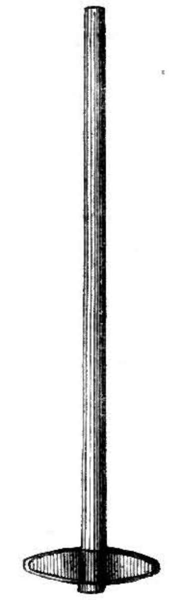
The tools used in road-making are few and simple. In working in clay, as in digging drains, &c., a narrow spade, considerably curved in the blade, called a *grafting tool*, is used. The best kind of *shovel* for road-work is represented in fig. 507; it is pointed in the blade, and has a curved handle to allow the labourer to bring the blade flat to the ground without stooping. Where metal rails can be laid down, a small *truck* or *wagon* holding about a cubic yard of earth can be used. Two kinds of *hammer*, one of which is represented in fig. 505, are used. The handle should be flexible and of straight grained ash, especially when used for breaking pebbles. The small hammer should have a chisel face, and the large one a convex face about five-eighths of an inch in diameter. They should be of cast steel rather than wrought iron. The *pronged shovel* (fig. 512) is useful for filling broken stones into carts or barrows, the advantage of this form being that the earth is not taken up with them. *Scrapers* are sometimes made of wood shod with iron, but those of plate iron are the best; the blade should be 6 inches deep and from 14 to 18 inches long, and turned round a little at the ends to prevent the mud, &c. from escaping. The *patent road-scraper* consists of a number of scrapers placed in a frame and mounted on wheels. It is worked across the road, and deposits the mud or dust at the side. Scraping keeps the road firm and hard, for the dirt retains water on the surface like a sponge: it also allows the surveyor to take advantage of the proper weather for repairing the roads, and it greatly assists fast travelling. A *sweeping machine* consists of a kind of endless broom, passing over rollers attached to a mud-cart, and so connected by cog-wheels with the wheels of the cart that when the cart is drawn forward the broom revolves and sweeps the mud from the surface of the road, up an inclined plane into the cart. A *hedging knife* or *plashing tool*, attached to a long handle, is also used for trimming hedges. *Working levels* are used in laying out new works and repairing old roads. Fig. 511 is a useful form of level. On the horizontal bar, *MP*, are four gauges, *a*, *b*, *c*, *d*, moving in dovetail grooves, so that when adjusted to a proper depth below the horizontal line, they can be fixed by thumb-screws. In this way the proper transverse section of the road is formed. A plummet in the centre of the level shows when the straight edge is horizontal, and a line drawn near the end of the bar at *M* marks the middle of the road; 4 feet from this the gauge *a* is fixed to the depth required by the curvature of the road, and the other gauges are in



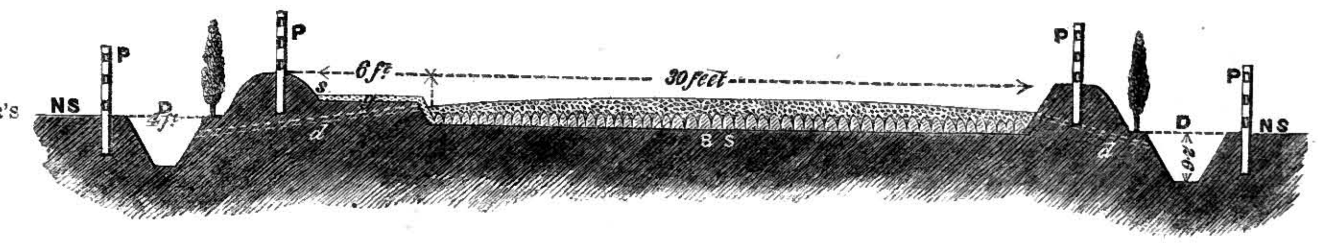
503. CROSS SECTION OF AN UNIMPROVED OLD ROAD.



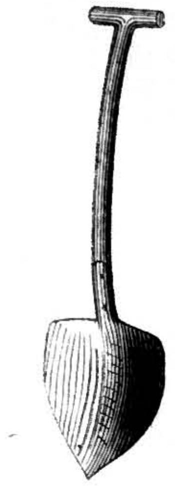
504. CROSS SECTION OF THE SAME ROAD WHEN IMPROVED.



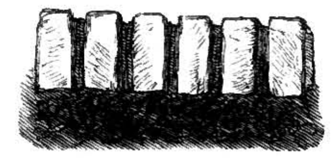
505. STONE-BREAKER'S HAMMER.



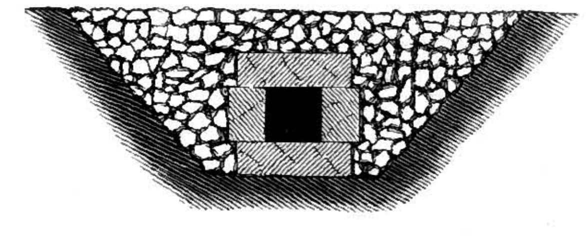
506. CROSS SECTION OF A NEW ROAD WITH A PAVED FOUNDATION.



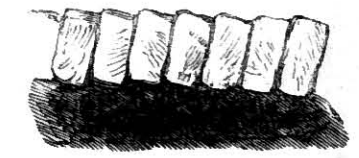
507. SHOVEL FOR ROAD-WORK.



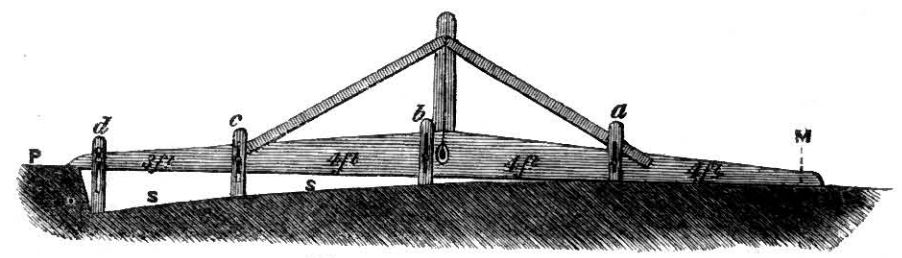
508. ROAD-PITCHING (*up hill*).



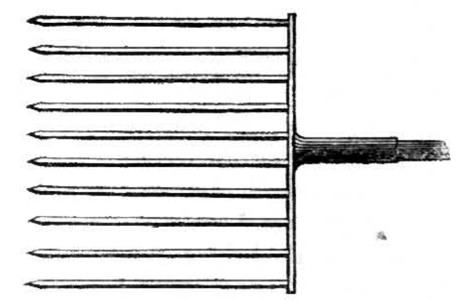
509. ROAD DRAIN.



510. ROAD-PITCHING.



511. WORKING LEVEL.



512. PRONGED SHOVEL.

513. STEPPING-STONES.

514. PRIMITIVE BRIDGE.

like manner arranged so that their lower ends shall coincide with the surface of a road 30 feet wide. Levels are also used for laying out slopes: such as a bar of wood 3 inches deep, 1 inch thick, and 6 feet long: near the middle of the rod is fastened a triangular piece of wood, so formed that when the rod is placed on a slope of from 1 to 2 or from 1 to 3, a pocket spirit level placed on one of the sides of the triangle shall be horizontal and the bubble remain in the centre.

Where the traffic is considerable, as in roads near or through towns, a good foundation is of the utmost importance. Indeed, it is customary to regard the foundation in any case as the real road, and the top covering or pavement as a contrivance for preserving it. The foundation may be of concrete or of broken stones, or the old road itself may be the foundation, but the stones must be taken up and relaid to the proper cross section, and upon this the stone pavement should be formed, the stones being bedded in some coarse kind of mortar. Granite is the best stone for paving, that of Guernsey or Aberdeen being preferred, as it does not become polished on the surface by wear. The stones should be in rectangular blocks from 8 to 15 inches in depth, about 18 inches in length, and 3 or 4 inches wide. Narrow stones wear better than wide ones. They must all be of the same depth, otherwise hollows will be formed on the surface. The courses should break joint, as in masonry or brickwork (figs. 163—168, 198—205), and there should be a firm kerb on each side of the road for the courses to abut against. The courses should be begun on each side and worked to the centre, and the last stone should form a key to the whole. The stones should then be rammed down with a heavy *punner*. After the pavement has been laid, it is usual to pour over it a thin grouting of sand and lime, but this is very inferior to bedding the stones in mortar. Where the inclination is considerable the pavement is laid, as in fig. 508, with a course of slate between the rows of stones, in order to give horses a hold for their feet, a result more usually obtained by placing the stones in a sloping position, as in fig. 510.

The enormous traffic of London tries the ingenuity of our road-makers, as well as the pockets of the ratepayers. When it is considered that London pavement costs about 20*s.* per square yard, and that in a crowded thoroughfare it requires frequent repair, and every few years relaying, we cannot wonder that persons are seeking new solutions to the problem how to construct a cheap, durable and not very noisy road. Wooden blocks, asphaltum, and other materials have been tried, but hitherto no *road-metal*, as it is called, has been found to resist the wear and tear of a London thoroughfare so well as a granite pitching on a good foundation.

XXV.—THE BRIDGE-BUILDER.

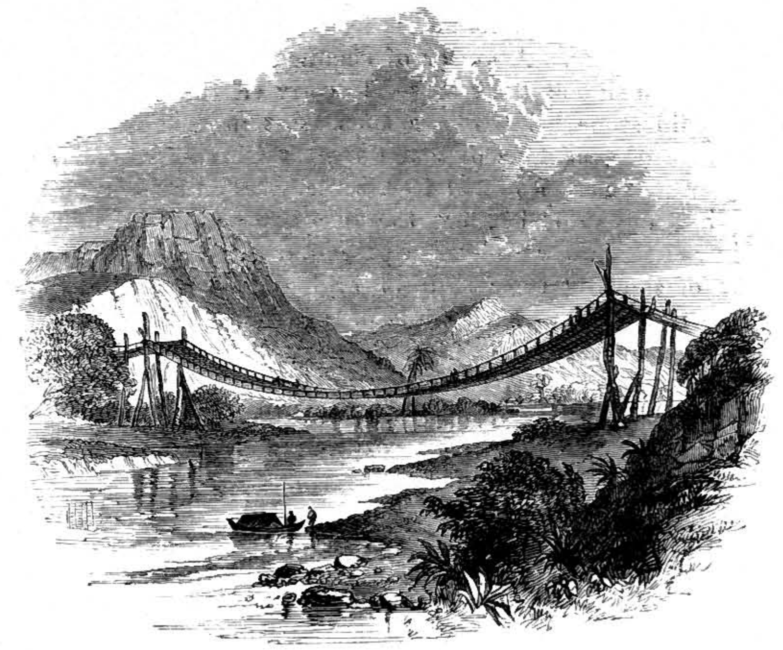
Bridge-building is a branch of road-making, a bridge being a constructed platform supported at intervals for the purpose of carrying a roadway over a strait, an arm of the sea, a river, a canal, a valley, or over another road. It differs from a *causeway* or *embankment*, where the roadway is continuously supported. *Aqueducts* for conveying streams of water or canals, and *viaducts* for carrying roads or railways, are practically bridges. The bridge must form not only a permanent roadway above, but allow easy passage for shipping in the stream below. In some cases, however, where the stream is wide and rapid, and liable to be beset with ice in winter, and from other causes a stone bridge is not practicable, a *bridge of boats* is used, as in fig. 518, in which a number of boats are moored in the stream, and a roadway is laid down upon them: in order to allow the passage of large craft, the traffic is occasionally interrupted, and a certain number of the boats or pontoons are swung aside to allow the vessels to pass.

The art of bridge-building varies greatly with the social and intellectual condition of the people among whom it is practised. The *stepping-stones* (fig. 513) across the brook are one of the most primitive forms of bridge; scarcely less so, is the *plank* resting on the two opposite banks. In the mountainous districts of South America, ropes made of rushes or leather are stretched across the stream, and connected and covered in some way so as to form a slight bridge. An elaborate kind of *rope bridge* is shown in fig. 515. Fig. 516 represents a *cane suspension bridge*, and fig. 517 a rude but efficient *timber bridge*.

The most permanent form of bridge is that of *stone*, with circular or elliptical arches. The Romans were great masters in the art of bridge-building, and some of their structures remain to the present day. The working and setting of the parts of a stone bridge belongs to the mason, as the art of combining the timbers of bridges belongs to the carpenter. Bridges of brickwork are built by the bricklayer, and those of iron by the smith and engineer; but, whatever the material, there is always an architect or engineer to preside over the work.

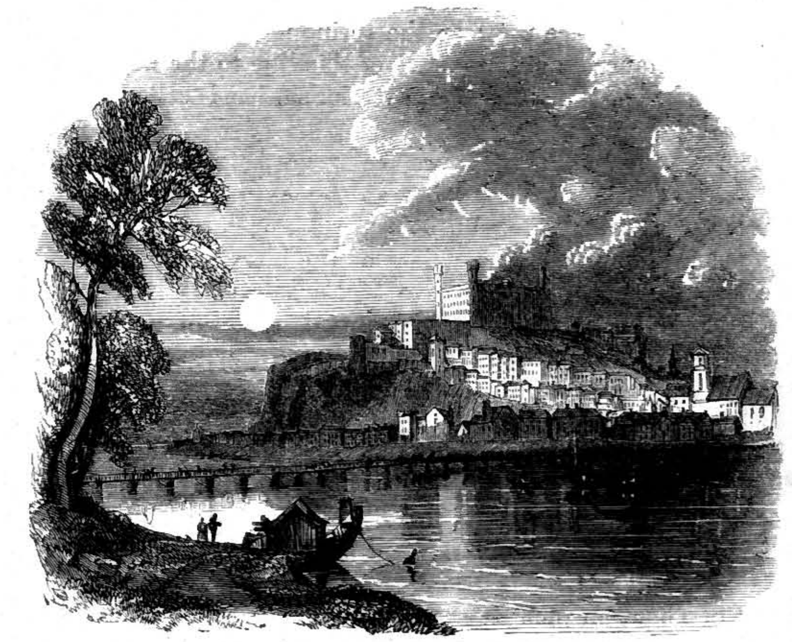
Of all these materials stone is the most durable, and is to be preferred. We shall therefore confine our few elementary details to the construction of this kind of bridge. In no building are the *foundations*, consisting of the underground work of the *piers* and *abutments*, of more importance, and various methods have been adopted for constructing them. In shallow rivers, stones were sunk to the bottom in strong baskets, and additional stones were piled up within them, until within a foot or so of the lowest water surface. Strong wooden chests or *caissons* were also filled with masonry aboveground, and sunk into the bed of the river, a plan adopted in forming the piers of the old Westminster bridge. In rapid streams, the ancient plan was to build the piers on dry ground by the side of the river, but ranging with its general direction, and at right angles with some direct approach previously agreed upon, and when the bridge was completed, to turn the course of the river by a new channel through the water-way of the bridge. Even where the course of the river was straight, or nearly so, it was so difficult and expensive to construct the piers in the water that the engineer did not hesitate in some cases to build a bridge on dry land, and then turn the river under it. If the bottom proved unsound, piles were driven over the site of the proposed piers, and the tops of the piles were covered with a coarse concrete of lime and gravel, and on this the first course of stone was laid.

In modern times, the *coffer-dam* allows the engineer to secure a firm foundation in the bed of the river. Suppose, for example, the pier of a bridge is to be erected in a tidal river, where there is a depth of 10 feet of water at the lowest spring tides, and that the bottom consists of 12 feet of loose gravel and sand resting on clay. If the depth at high-water be 28 feet, we thus get a depth down to the clay of not less than 40 feet. In such case the coffer-dam must be formed of four rows of piles, as shown in the transverse section (fig. 521), and the spaces between them must be filled with clay-puddle, thus forming three distinct *puddle walls*. The whole having been made water-tight, the water can be pumped out from the inclosed space, and the ground excavated for a foundation as on dry land. A cheaper method introduced of late years, is to sink large wooden caissons, closed at top, and by means of compressed air to drive the water out by a central shaft. The ground is then excavated at the bottom of the caisson; and concrete and masonry filled in. Hollow iron piles are also used as piers, or for their foundations. The piers should intercept the water-way of the river as little as possible, but their thickness must be regulated by their height as well as by the span and rise of the arches. Under low-

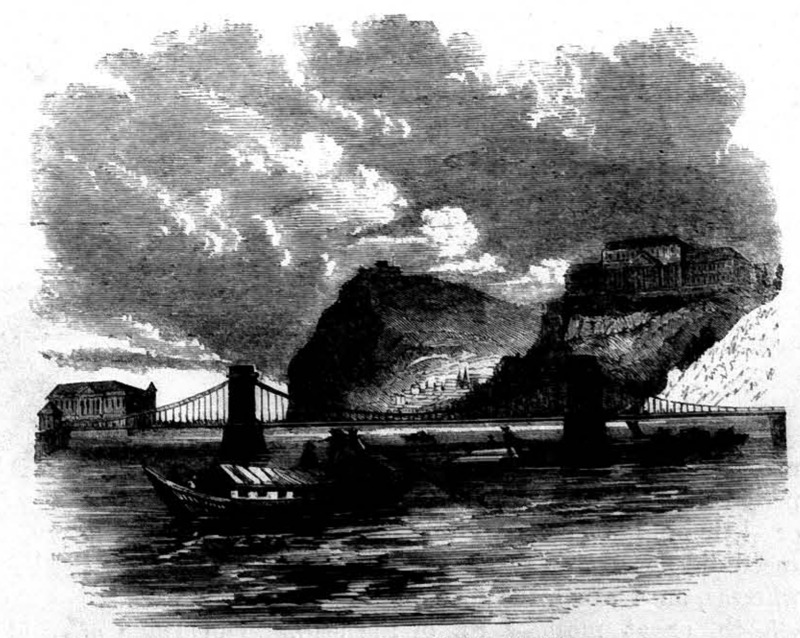

515. ROPE BRIDGE.


516. CANE BRIDGE, CEYLON.


517. BRIDGE AT NORWICH, CONNECTICUT.


518. BRIDGE OF BOATS.


519. PONT Y PRIDD, WALES.


520. SUSPENSION BRIDGE, PESTH.

water the piers should increase in breadth to the foundation, and the exposed ends should be provided with sharp angles to act as *cut-waters*. In building the pier, provision should be made for the *abutments* of the arches, and also for supporting the *centre:* this is a timber framing required for supporting the separate stones or *voussoirs* of the arch, until they are keyed in. The centre must be strong enough to bear the weight of the voussoirs without any sensible change in form, and admit of being easily removed when the arch is finished. A good deal of skilful carpentry has been expended on the construction of centres, and eminent bridge-builders, in the detailed accounts of their several structures, usually describe with great minuteness the construction of the centre. The form and dimensions of the arch-stones or voussoirs vary greatly, from a depth of 6 feet to $2\frac{1}{2}$ feet or less. Each course should be of equal thickness quite through, and the beds should be worked as true as possible for the whole breadth of each stone. The key-stones should be driven in so as to fill their places firmly, and, when finished, the work should be left for some time to dry and get hard. In the meantime the outside work is being proceeded with, and when the centre is at length removed, the interior surface of the arch, called its *intrados* or *soffit*, is carefully examined. The key-stone occupies the highest point or *crown* of the arch: those parts of the pier from which the arch springs are called the *abutments*, and the points where the intrados meets the abutments, the *springings* of the arch, and just above this are the *flanks* or *haunches* of the arch. The horizontal space between the springings is the *span* of the arch, and the distance from the centre of this line to the key-stone is the *rise* or *height* of the arch. The exterior surface is called the *extrados* or *back* of the arch.

The *spandrels* of a bridge are the spaces between the haunches of an arch and its highest point at the extrados of the roadway. These spaces may be filled up with earth or gravel, or they may be formed into vaults. The points of the piers are brought up and finished at some distance above high-water mark by sloping them back to the face of the spandrel in a triangular or circular form, or disposing them to receive columns, pilasters, or turrets. When the spandrels have been brought up to the level of the top of the arch-stones, they are dressed into the slope which it is proposed to make the roadway. A cornice is usually laid down, extending along the whole of the arches, spandrels, and wing walls. There is also a *parapet* consisting of a *plinth*, *dado*, and *coping*. The parapet may be from $3\frac{1}{2}$ to 6 feet above the footpath or roadway. The dado or middle member is about 10 or 12 inches thick; the plinth has an offset of about an inch on each side, and the coping is usually made to slope each way from the middle. Balustrades are sometimes introduced instead of the dado. When the spandrels have been covered, the foundations for the footpaths are built with rubble-stone for the outside kerbing. The footpaths may vary from 3 to 6 feet in breadth. If the carriage-way is to be paved, there should be laid on the covering of the spandrels and over the top of the arches, a thick bed of gravel mixed with loam, in which squared paving-stones are to be set and well beaten, so as to make a curve across the road of 4 inches in 24 feet in breadth. But if the roadway be of gravel, it must be laid 22 inches in depth in the middle, and 18 inches near the sides. A gutter of small squared stones should be formed on each side of the roadway to carry off the water.

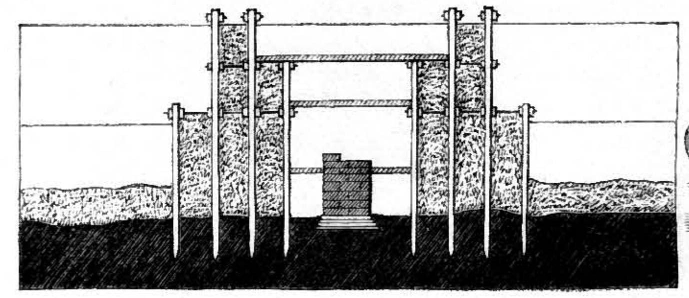
Some splendid stone bridges have been built in modern times. The fine bridge of sandstone over the Dee at Chester has for its centre circular arch a span of 200 feet, while London Bridge, built of granite, has a span of 152 feet, the form being elliptical. The extensive introduction of railways has given our engineers abundant opportunity of showing their skill in bridge-building; thus the railway bridge at Maidenhead, built of bricks, laid in cement, presents elliptical arches of 128 feet in span; they are among the flattest arches known. This latter bridge is the boldest that was ever constructed, considering the material and the form of the arch, the very heavy traffic to which it is exposed, and the tremor and vibration consequent thereon.

In countries where timber is plentiful, timber bridges have obtained considerable celebrity, on account of the scientific carpentry concerned in their production. We may also refer to *suspension bridges*, which in many cases may be quite independent of the bed of the river which they cross. A suspension bridge may be often erected where, from the rapidity of the current, or the height of the banks, a stone bridge would not be practicable. A bridge of this kind, however, is much slighter than one of stone, so that where the traffic is heavy and considerable the latter must be preferred; but for large openings, where the traffic is small, the suspension principle is good; for the bridge can be carried to almost any span and any height at a comparatively small cost. The *rope bridge* (fig. 515) and the *cane bridge* (fig. 516) are quite as much suspension bridges as the more important structure, fig. 520. A suspension bridge, as usually constructed, consists of a chain or set of chains, secured by their extremities to solid rock or masonry on each side of the stream, and then passing over the tops of piers arranged for the purpose, falling down by their own weight into a catenary curve over the stream. From this chain the roadway is hung by means of vertical rods, so that, from the method of suspension, the road is subject to constant vibration, not only from the traffic, but also from the action of wind. The links of the chain are of very large size, as may be seen from the specimen, fig. 522.

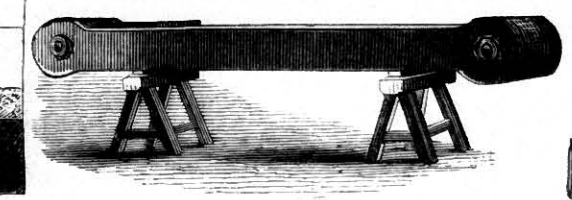
Of late years, *iron girder* and *tubular* bridges have come into use in consequence of the increased facility with which iron is now manufactured. An iron bridge usually consists of ribs of cast iron, supporting perpendicular spandrel pieces of the same material upon which the roadway is carried. In girder bridges wrought iron is substituted for cast, for which purpose plates of rolled iron were originally joined with rivets with a strap of angle-iron attached on each side, top and bottom, so as to form artificial flanges. Greater strength was obtained by adopting the tubular form, using T-iron for the vertical ribs and arranging the side plates vertically. The finest example of the tubular bridge is that over the Menai Straits, fig. 538, while the section, fig. 539, will give some idea of the structure of the tube.

XXVI.—THE CANAL ENGINEER.

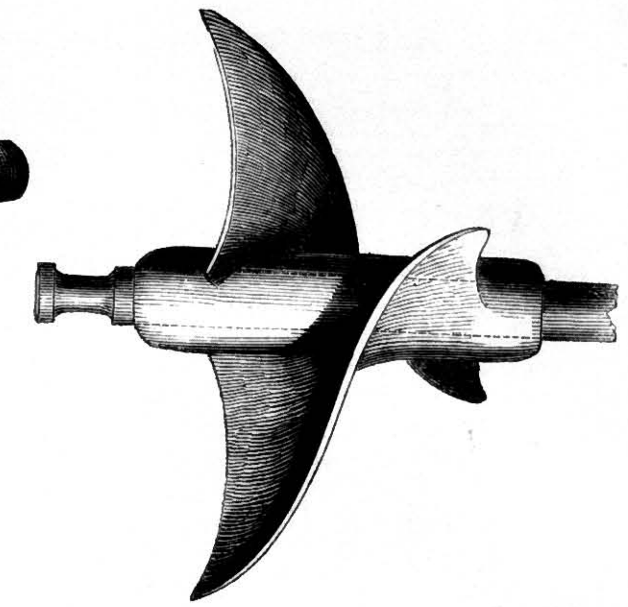
It was not until the year 1758 that those useful auxiliaries to roads, *navigable canals*, were introduced into this country. At this period the force of traction on our best roads was not less than $\frac{1}{8}$th or $\frac{1}{10}$th of the load or carriage, and when this was heavy, the speed did not exceed two miles, or two and a half miles per hour; whereas, on a canal, the force of traction at that pace is not above $\frac{1}{1000}$th, or at most $\frac{1}{900}$th, of the load. The Duke of Bridgewater, with the assistance of his engineer, the celebrated Brindley, made these advantages manifest, so that between the dates of the completion of the Bridgewater Canal and the opening of the first railroad in 1830, not less than 2,200 miles' length of navigable canals had been constructed in England alone; while, in addition to canals, such rivers as were capable of it were rendered navigable. The introduction of railroads has not only not superseded canals, but in some cases has actually improved their traffic, since the tendency of a railway is to increase traffic, and the com-



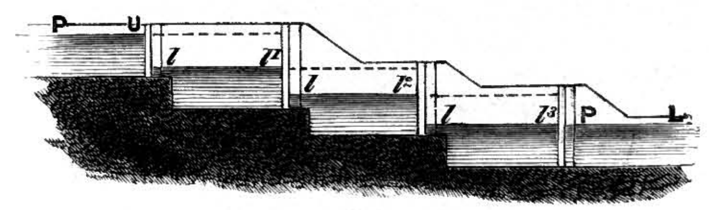
521. COFFER DAM.



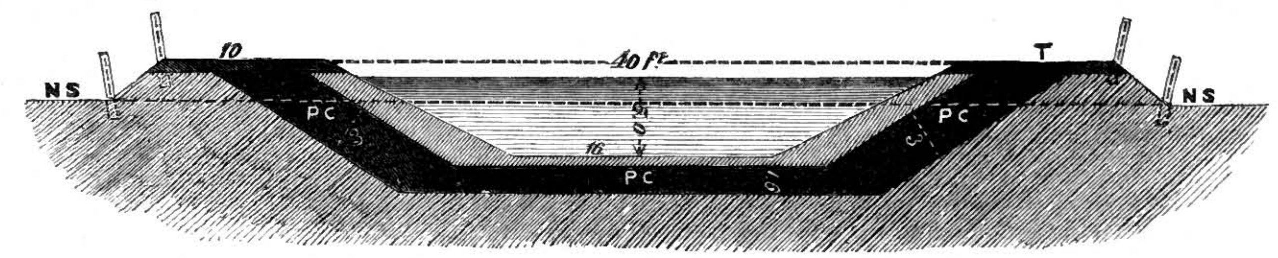
522. LINK OF SUSPENSION CHAIN.



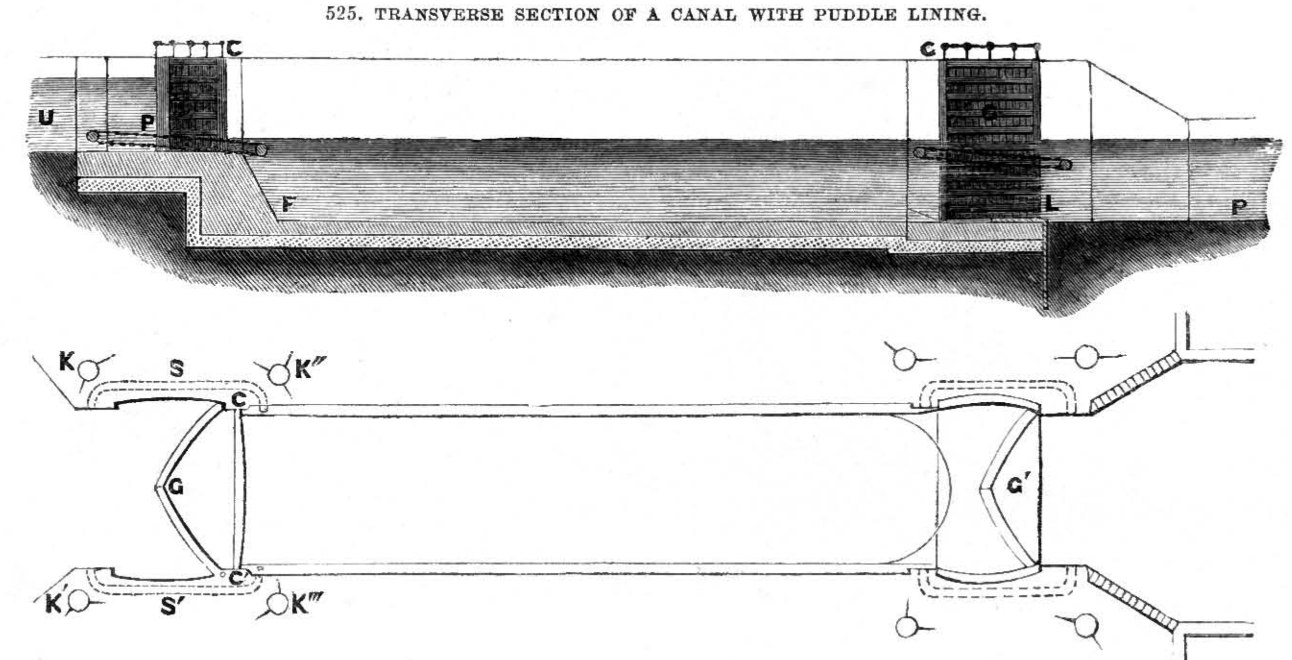
524. SCREW.



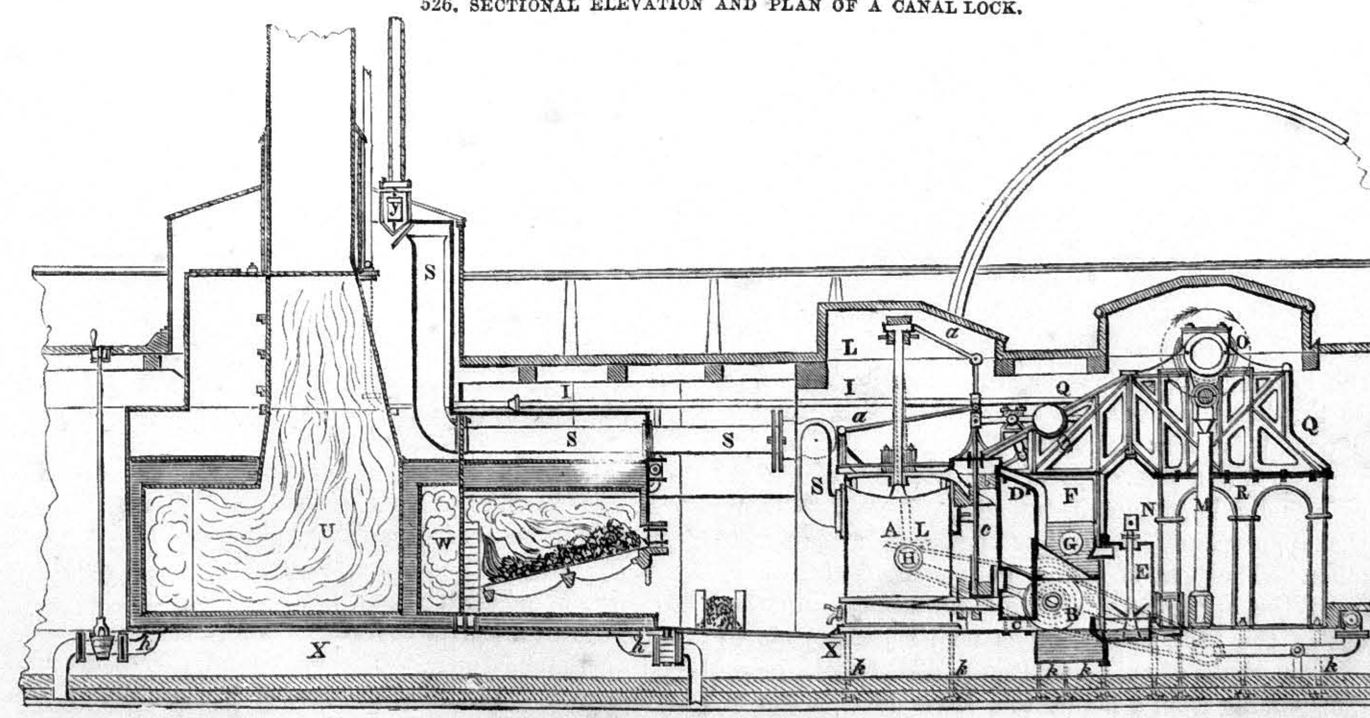
523. SERIES OF LOCKS.



525. TRANSVERSE SECTION OF A CANAL WITH PUDDLE LINING.



526. SECTIONAL ELEVATION AND PLAN OF A CANAL LOCK.



527. SECTION OF A MARINE ENGINE.

paratively low rate of water-carriage insures to the canal its share of business.

In the construction of a canal, the engineer has to consider how he can best construct his watery road on a perfect level, or series ot levels. This is done by one of three methods, such as by raising the depressed portions by means of embankments and aqueducts; secondly, by depressing the elevated portions by means of cuttings and tunnels, both which methods are common to the road-maker and the railway engineer; but the third method, which is peculiar to the canal engineer, is by forming a series of stairs or steps called *locks*, by which one level portion is made to communicate with another, either higher or lower than itself, the water being maintained at the higher level by means of gates so placed that the fluid pressure shall keep them closed.

The form of channel adopted for the canal is such that, except in tunnels, where the sides may be vertical, the bottom is made to slope off upwards, the amount of slope depending on the nature of the soil. Where the soil or rock is so porous that the water filters through, the excavation is usually lined with a thickness of from 1½ to 3 feet of puddled clay, or clay well beaten up or tempered with mortar, and then mixed in a certain proportion with gravel, sand, or chalk; for if clay were used alone, and the water sank below the usual level, the clay would crack, and when the water rose again, would escape by the cracks. It is also usual to form a trench three or four feet in width, in the middle of each side bank, to at least three feet below the bottom of the canal; and this *puddle-ditch*, or gutter, is filled up with puddling stuff, its chief object being to prevent rats and vermin from perforating the banks. In fig. 525, *P C* represents the puddle-lining, 1 foot 6 inches thick at the bottom, and 3 feet in the slope; *T* is the towing path, 10 feet wide; *N S* the natural surface.

It has been stated that the ascent to a higher level or the descent to a lower one is made by means of locks. The level portions between the locks are termed *pounds*, and the frequency with which locks and pounds alternate will of course depend upon the undulations of the ground. If this rise uninterruptedly, or rise and fall at short intervals, the pounds will be short and the locks frequent; while, if the ground be tolerably level, few locks will be wanted. A single lock usually consists of an oblong chamber about 70 or 80 feet long, *CC′* (fig. 526), and 7 or 8 feet wide. Its sides and *invert*, or floor, are lined with brick or stone. It is by means of this chamber that an upper pound is connected with the pound next below it, or a lower pound with the next upper one. Thus *UP* is a portion of the upper pound, and *LP* of the lower pound, which is on the same level as the floor of the lock chamber. *PG* are the gates which retain the water at the upper level: they are curved, as shown in the lower figure, and when in motion, turn upon their ends *CC′*, as centres. They are wide enough to meet and form an angle at *G*, so as mutually to support each other, and the pressure of the water against them keeps them more closely shut. They are opened by means of *capstans*, *KK′*, working chains attached to the gates under the water, and passing through tunnels in the sides of the lock. They are closed by two other capstans, *K″ K‴*, the gate, *CG*, being shut by *K‴*, and the gate, *GC′*, by *K″*. A similar pair of gates is placed at the lower end of the lock, *CL*; they are on the same level as the upper gates, and consequently have a greater length than those, in proportion as the lower pound is above the upper. When a barge has to pass from a lower to an upper level, and arrives at the lower gates, *LG′*, these are opened, and on the boat passing into the lock-chamber, are closed behind it. Water from the upper pound is now let into the lock-chamber by opening the channels *SS′*, in the sides of the upper part of the lock, which are usually kept closed by sluices. Water then pours in from the upper pound, and raises the level of the water in the lock chamber. The boat of course rises with it, and when the flow has ceased, the upper gates, *G*, are thrown open, and the boat is towed out of the lock, and proceeds on its journey along the upper level. The whole of this operation is called *locking-up*. In *locking-down*, or passing from a higher to a lower level, water is admitted into the lock from a higher level, the gates are opened to admit the boat, and are then closed upon it, while the sluice is opened in the opposite gates for letting out the water until its surface in the lock chamber coincides with that of the lower level. The gates are then opened, and the boat is towed out as before. Thus it will be seen that a series of locks form a kind of liquid staircase by which the boat may ascend or descend without ever ceasing to float, by varying the level of the water in the enclosed space. In this arrangement a certain quantity of water is lost from the higher level, but by making the locks double, so as to allow the boats to pass alternately up and down, only one lockfull is required between each pair, since every ascending boat requires a lockfull of water, and leaves the lock full, and every descending boat finding the lock full, does not draw upon the upper pound for water.

Where the slope is considerable, a chain of locks is formed (fig. 523), so that the lower gates of one chamber may form the upper gates of the next below it. In this way only one more than half the number of gates for the whole of the chambers (supposing them to be detached) is required, and much of the machinery for opening and shutting them is saved. In this arrangement there is a great waste of water in certain cases, as for example:—

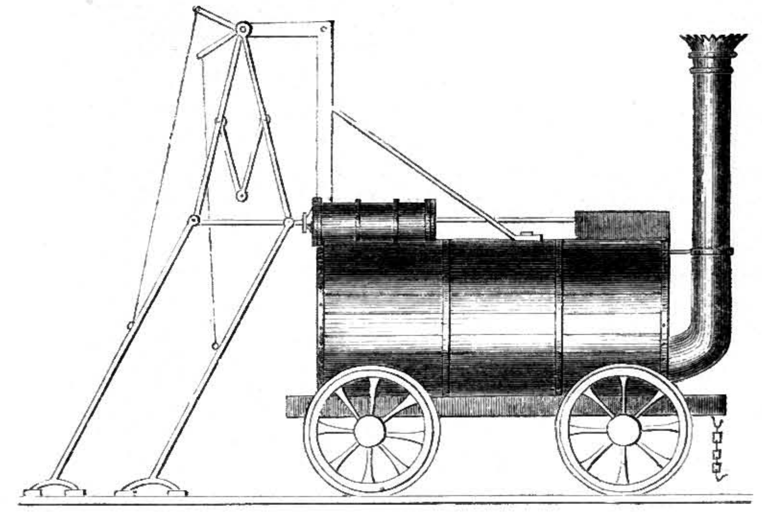
	Finds the locks,	*Lets out of the upper chamber,*	*Leaves all the locks,*
Boat descending.	Full.	None.	Empty.
	Empty.	One lockfull.	Empty.
Boat ascending.	Full.	One lockfull.	Full.
	Empty.	As many locksfull as there are contiguous chambers.	Full.

When the chambers are said to be empty, it is not meant that they contain no water, but that the water is in each at its lower level ll^1 ll^2 &c. (fig. 523), the dotted lines showing the levels in the full locks. Hence, when a number of boats follow each other in the same direction, up or down, each boat will require one lockfull of water; but if a number of boats pass alternately up and down, each pair will require between them as many locksfull as there are contiguous lock-chambers, which in the case of fig. 523 is three, for the previous boat having left all the chambers empty, the ascending boat will require three locksfull, but as it leaves all the chambers full, the next descending boat will not draw off any water from the upper chamber.

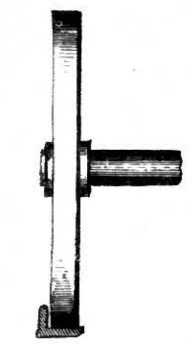
By means of the *double lock*, one half of the water which would otherwise escape to the lower level is saved. The double lock consists of two oblong chambers placed side by side, separated by a brick partition, in which is a sluice connecting the two chambers. Now, supposing one of these chambers filled to the level of the upper pound, and the other chamber to that of the lower pound, a boat about to ascend would be towed into the chamber where the level was lower, and all the gates being closed, the water from the full chamber would be let into the other, until there was an equality of level in both. The sluice would then be closed, and water admitted from the higher pound, by which the barge would be raised to the higher level, and the upper gate being opened the barge would be towed out.

It is important to economize the water of the canal as much as possible, since the canals are constantly losing water from the locks and from evaporation, and the supply is by means of natural springs and rain. In some cases it is necessary to collect the flood-waters of higher grounds into reservoirs for feeding the canal when required. In dry weather it has even been found necessary, in order to maintain the traffic of the canal, to purchase water from the neighbouring water companies.

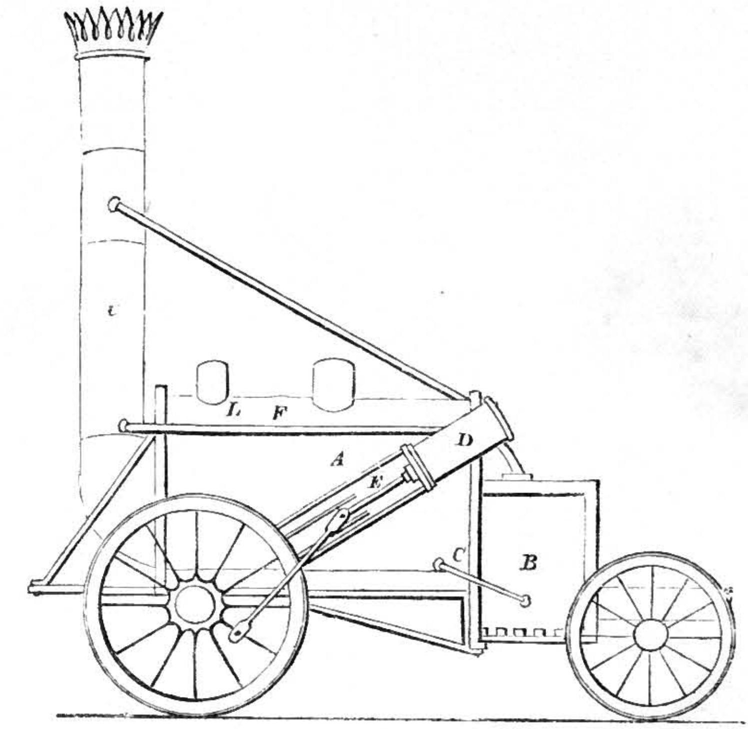
The boats or barges used on canals are much longer and narrower than those used for river navigation, the form being favourable to speed and ease of draught. What are called *fly-boats* have flat bottoms, and the goods are stowed in them nearly from end to end, and to some height above the edge of the boat, the whole being protected by a canvas covering. There is a small cabin at the stern end for the boatmen. The boats and barges are *tracked* or towed by one or two horses, at the rate of 3 or 4 miles an hour: there is a



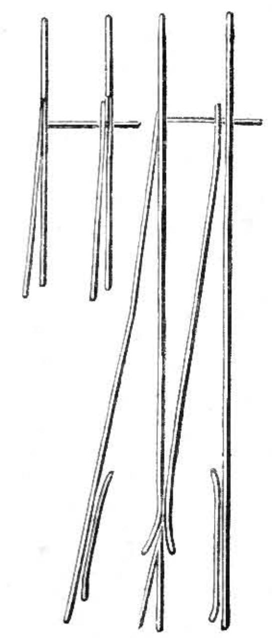
528. BRUNTON'S "MECHANICAL TRAVELLER."



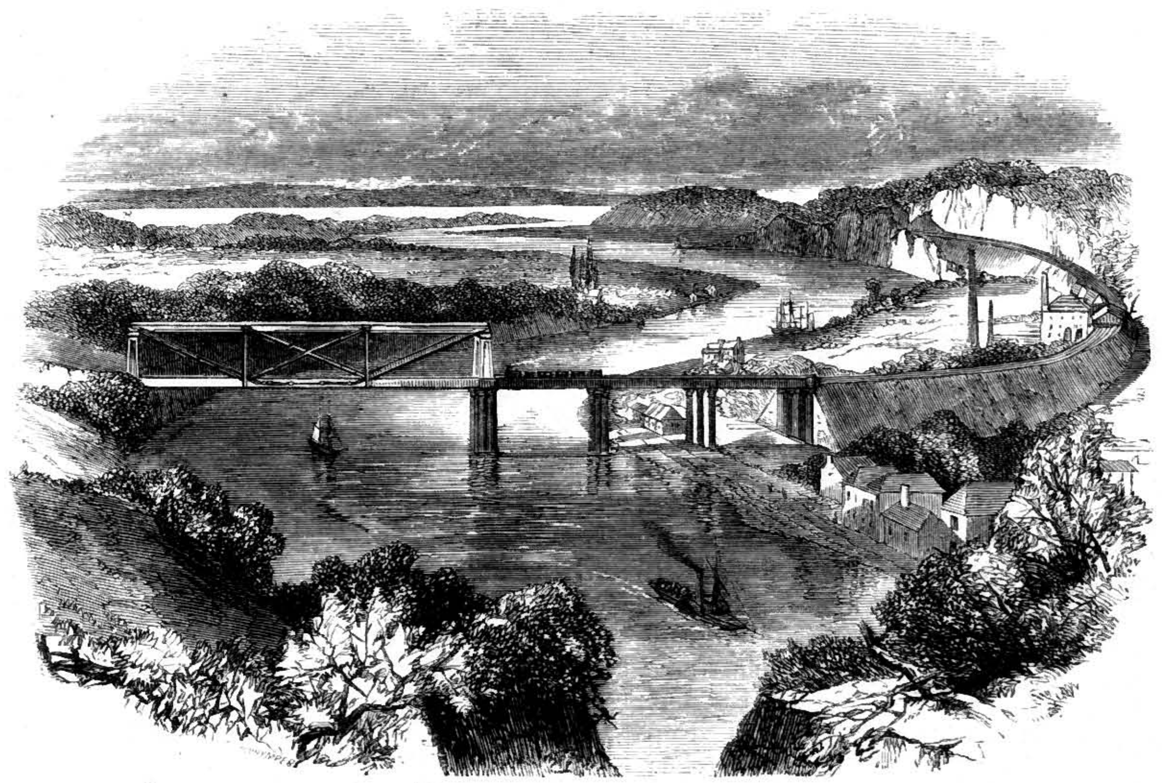
529. WHEEL ON TRAM-PLATE.



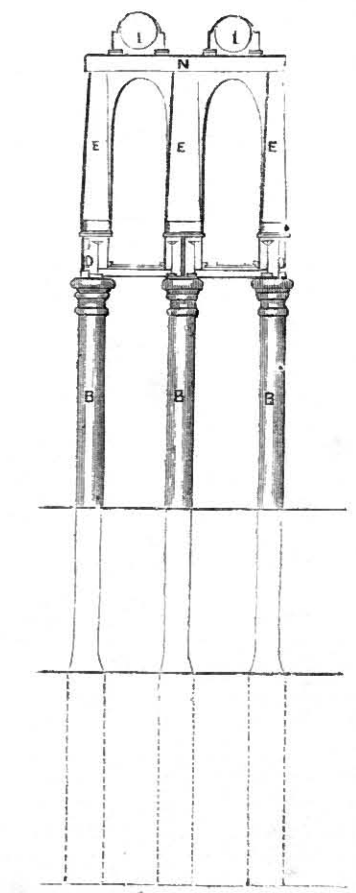
530. THE "ROCKET."



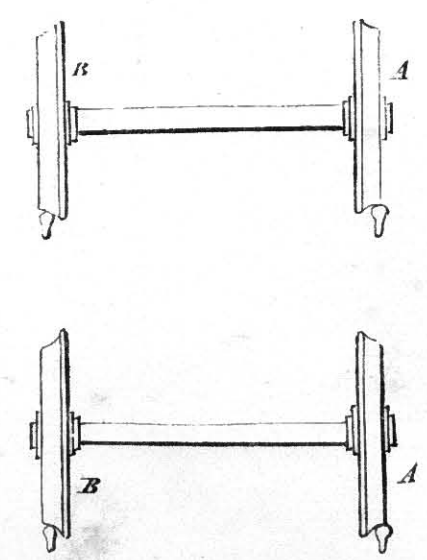
SW.TCHES AND POINT



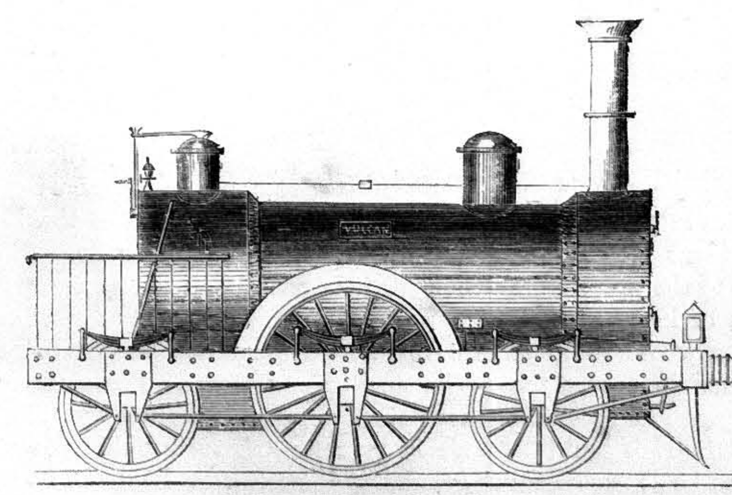
532. BRIDGE OVER THE WYE.



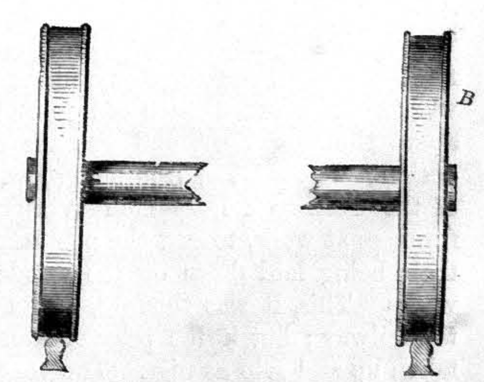
534. TOWER FOR TUBULAR BRIDGE.



534. CONICAL STRUCTURE OF WHEELS.



535. MODERN LOCOMOTIVE ENGINE.



536. EDGE-RAILS.

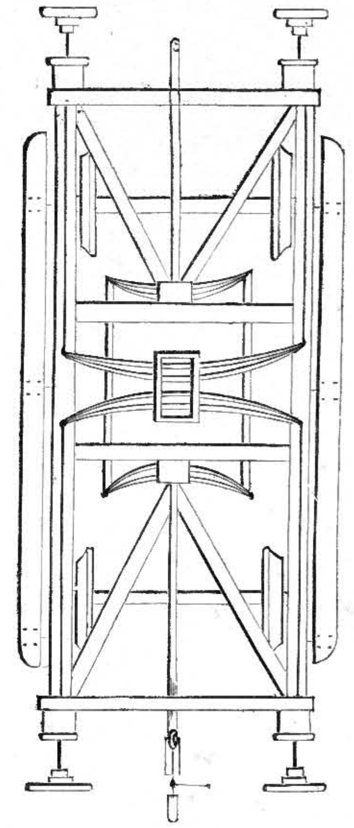
towing path at the side, and the horse is connected with the boat by means of a long rope. Passenger-boats are used on some canals, moving at the rate of 9 or 10 miles an hour; they are 70 feet in length and about 5½ broad: they carry from 70 to 100 passengers, or more. Each boat is drawn by two horses, which are changed every 4 miles. They go at a gallop, and the speed is not found to injure the banks of the canal. Steam machinery has also been introduced into canal-boats with considerable effect: paddles, even supposing there were room for them, would be likely to injure the banks, so that the *screw* (fig. 524) is of great value as a means of propulsion. The section (fig. 527) does not belong to canal navigation, but is introduced to fill up the vacant space, and will be described hereafter.

It may be noticed here, that the *navvies*, who execute the earth-work of railways, derive their name from the term *navigable canals*. The tendency to abbreviate, which may be noticed in a busy energetic people like the English, has converted *navigable canal makers* into the now familiar word *navvies*.

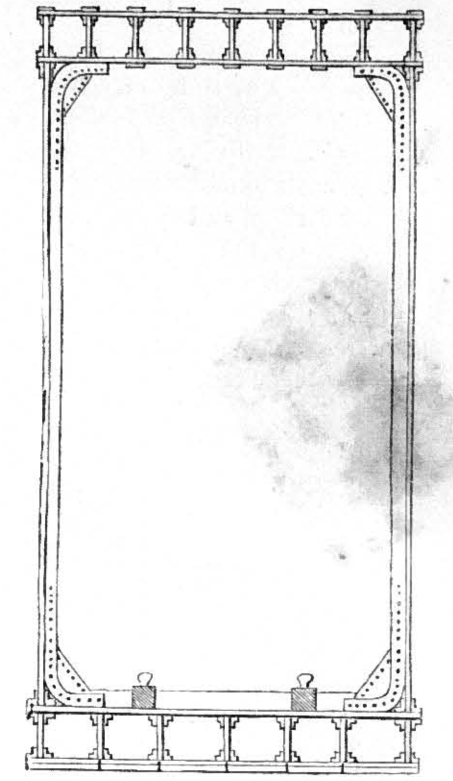
XXVII.—THE RAILWAY AND MARINE ENGINEER.

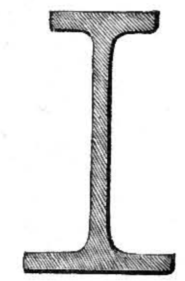
In a railway or railroad, rails of iron are laid down on a solid foundation, in order, by their smoothness, to assist the motion of wheel carriages. We are accustomed to associate a railway with a locomotive engine, drawing a long train of carriages, but a moment's consideration will show that the locomotive is not necessarily a part of the railroad, for the carriages may be, and in some cases are, drawn by horses; or they may descend inclines by their own gravity, as was practised in the colliery districts before the locomotive was invented; or the carriages may be drawn along levels and up inclines by means of stationary engines, a plan still adopted for portions of certain railways where the incline is too steep for a locomotive to ascend by itself.

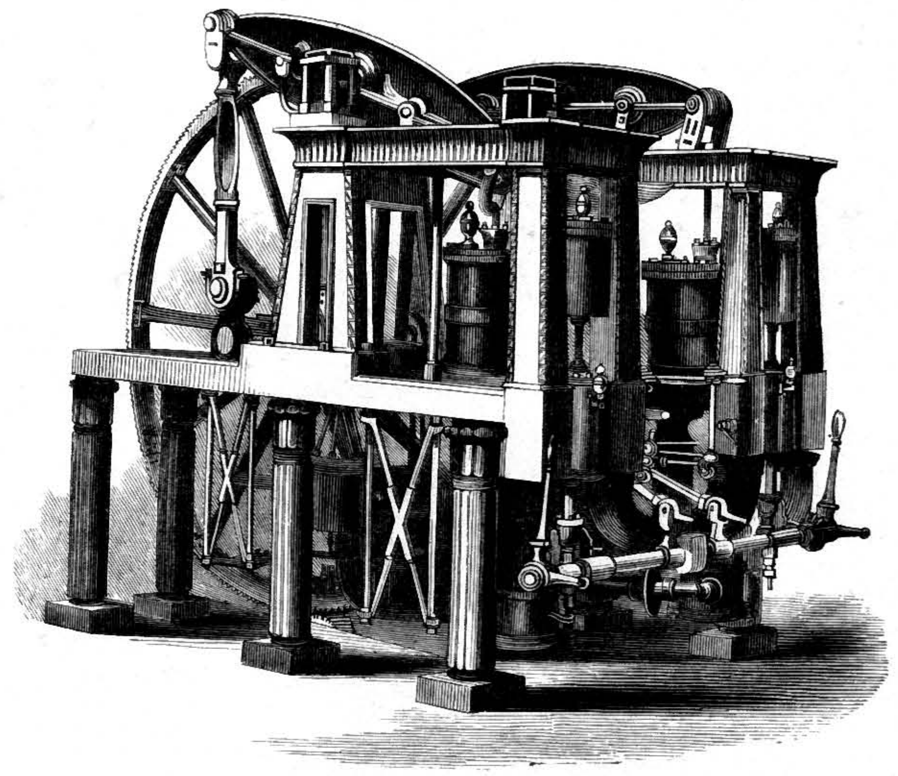
Nearly two centuries ago, the colliers in the north of England made use of wooden rails, or *tram* or *wagon-ways* for the purpose of lessening the friction of a common road, and thus reducing the labour of drawing coals from the pit's mouth to the place of shipment. They consisted of pieces of wood embedded in the road, so as to form smooth tracks for the wheels of the wagons, and it was found that by this means the horses could perform a much greater quantity of work. They were afterwards improved by levelling the road, and placing roughly-squared pieces of wood across it, called *sleepers*, as at *A* (fig. 544). They were about six feet in length, and from four to eight inches square, and two or three feet apart. Upon these other pieces, *B*, about six or seven inches wide, and five inches deep, were fastened by means of pegs, so as to form two wheel-tracks about four feet apart. In our figure only one of these tracks is seen, as the rail is viewed from the ends of the sleepers. The spaces between the sleepers and under the rails were filled up with ashes or gravel; in this arrangement, the removal of a broken or worn-out rail injured the sleepers, and made the peg-holes too large. A second set of rails, *C*, was therefore spiked down upon the first. The wagons used on these wooden railways contained about two or three tons of coal each, and were mounted on small wheels furnished with a flange or projecting rim, which came in contact with the side of the rail and kept the wagon in its place. In places where the ascent was steep, friction was further diminished by nailing to the wooden rails thin plates of malleable iron. In descending steep inclines, or *runs* as they were called, the speed was checked by a piece of wood, called a *break* or *convoy*, which was forcibly pressed upon one or both of the wheels on one side of the wagon. The introduction of iron instead of wooden rails took place about the year 1767, and was the result of accident rather than design. The price of iron being low, it occurred to the proprietors of the Colebrook Dale Iron Works, as a means of keeping their furnaces at work, to cast the pigs in such a form as would admit of their being laid down on the wooden railway then in use at the works. This, it was thought, would save the expense of repairing the railway; but if the price of iron should rise, the rails could be taken up and sold as pigs. The road was found to be so successful that it excited some attention, and it was thought at the time to be an advantage, that vehicles could be easily turned off the track, in consequence of the absence of a guiding flange. This, however, was soon recognised as a defect when anything like speed was required on the line; and about the year 1776, the Colebrook Dale rail was improved by the addition of an upright flange, fig. 529. A rail of this kind is called a *plate-rail*, or a *tram-plate*, the latter term being derived from Mr. Outram, an extensive colliery proprietor, who patronised the new form of road, and they were first called *Outram roads*. They are still in use in mining districts, stone blocks being substituted for wooden sleepers. It will be seen that the tram-plate is a flat plate of metal with an upright flange, and it is curious that although the rails have long been changed in form, and bear no resemblance to plates, the men who attach them to what is termed the *permanent way* are still called *plate-layers*. The form of the tram-plate allowed stones or dirt to lodge upon it, thus obstructing the wheels and impeding the draught. These objections were got rid of by the introduction of *edge rails* (fig. 536), about the year 1801. They first came into extensive use at the Penrhyn slate quarries, for conveying slate to the port of Bangor in North Wales. The rail was about four and a half feet in length, and at each extremity was a dove-tail block, which fitted into an iron sill embedded in the road: the wheels had a grooved tire fitting loosely on the rail. Notwithstanding many defects in this arrangement, such was the saving of power, that ten horses were able to do the work, before required of 400, on a common road. A few years after this a better form of rail was contrived; namely, the *fish-bellied rail*, in which the lower edge was curved, so as to give the rail greater depth in the centre than at the ends or points of support. The rails were cast in lengths of three or four feet, and the ends were so contrived as to form a half-lap joint, which fitted into a cavity in a cast-iron chair, spiked down to a stone or wooden sleeper. Fish-bellied rails have been superseded by *parallel* rails, or those which have an equal depth from end to end. Rails were further improved by making them of malleable instead of cast-iron. They are formed at the rolling mill in lengths of from fifteen to twenty-four feet, whereby the number of joints is diminished. The weight of the rails used on the first public railway with locomotives, namely, the Liverpool and Manchester, was 35 lbs. per yard: whereas, the weight of the rails now in use varies from 44 to 84 lbs. per yard. But a heavy rail of wrought iron was not sufficient to resist the increased weight of the locomotive (from 30 to 35 tons) and the all but incessant traffic. The iron was rolled off in thin flakes which float about in the air and enter the carriages, so that it was possible to collect a quantity of these shining particles on a journey. To prevent this waste, steel rails have been introduced. The steel is made by the Bessemer process, in which a number of tons of good iron are melted and run into a vessel through which air is blown so as to bubble up through the melted mass. The oxygen of the air seizes hold of the carbon of the iron and removes it in the form of a gas. The iron being thus *decarbonized*, a

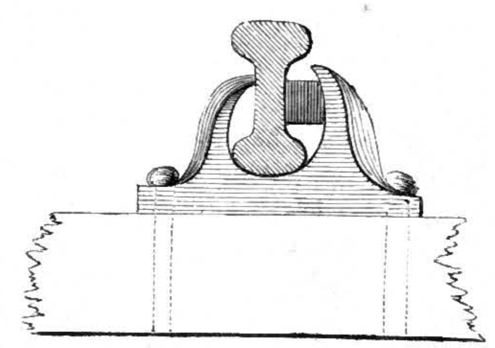

537. BUFFERS AND DRAW-BARS.

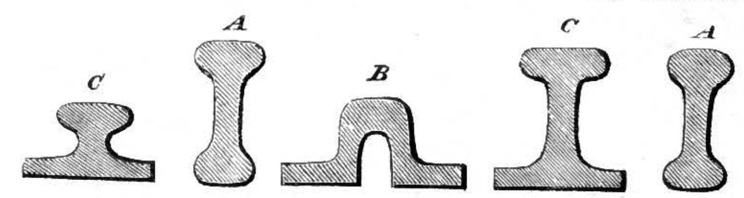

538. MENAI TUBULAR BRIDGE.


539 SECTION OF TUBE, BRITANNIA BRIDGE.

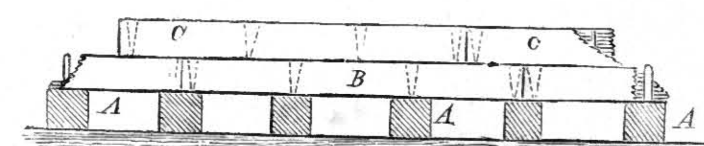

540. SECTION OF GIRDER.


541. WORKING PARTS OF A MARINE ENGINE.

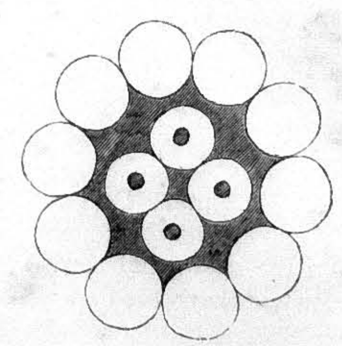

542. RAIL AND CHAIR.

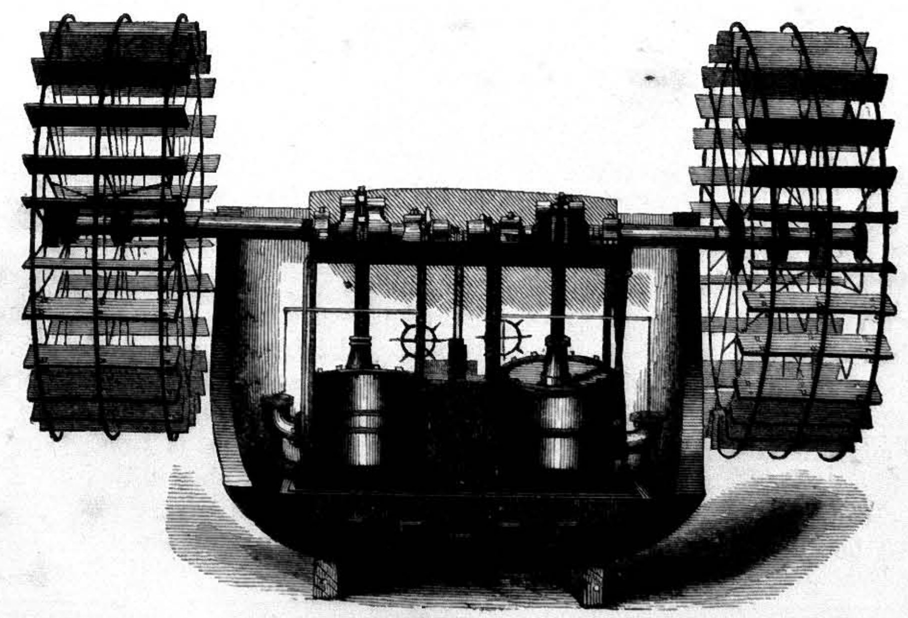


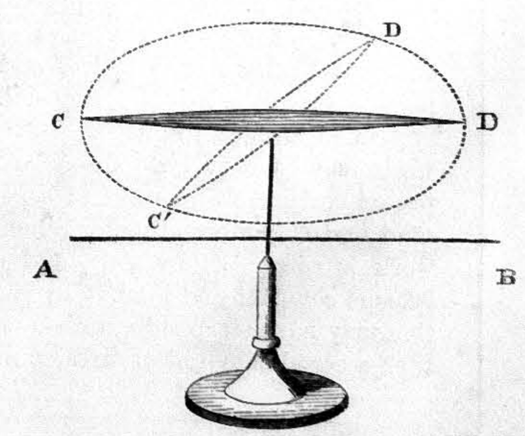
543. CROSS SECTION OF RAILS.



544. A, SLEEPERS; B, PRINCIPAL RAIL; C, UPPER RAIL.


545. SECTION OF MARINE CABLE.


546. MARINE CONDENSING ENGINE. (Boulton and Watt.)

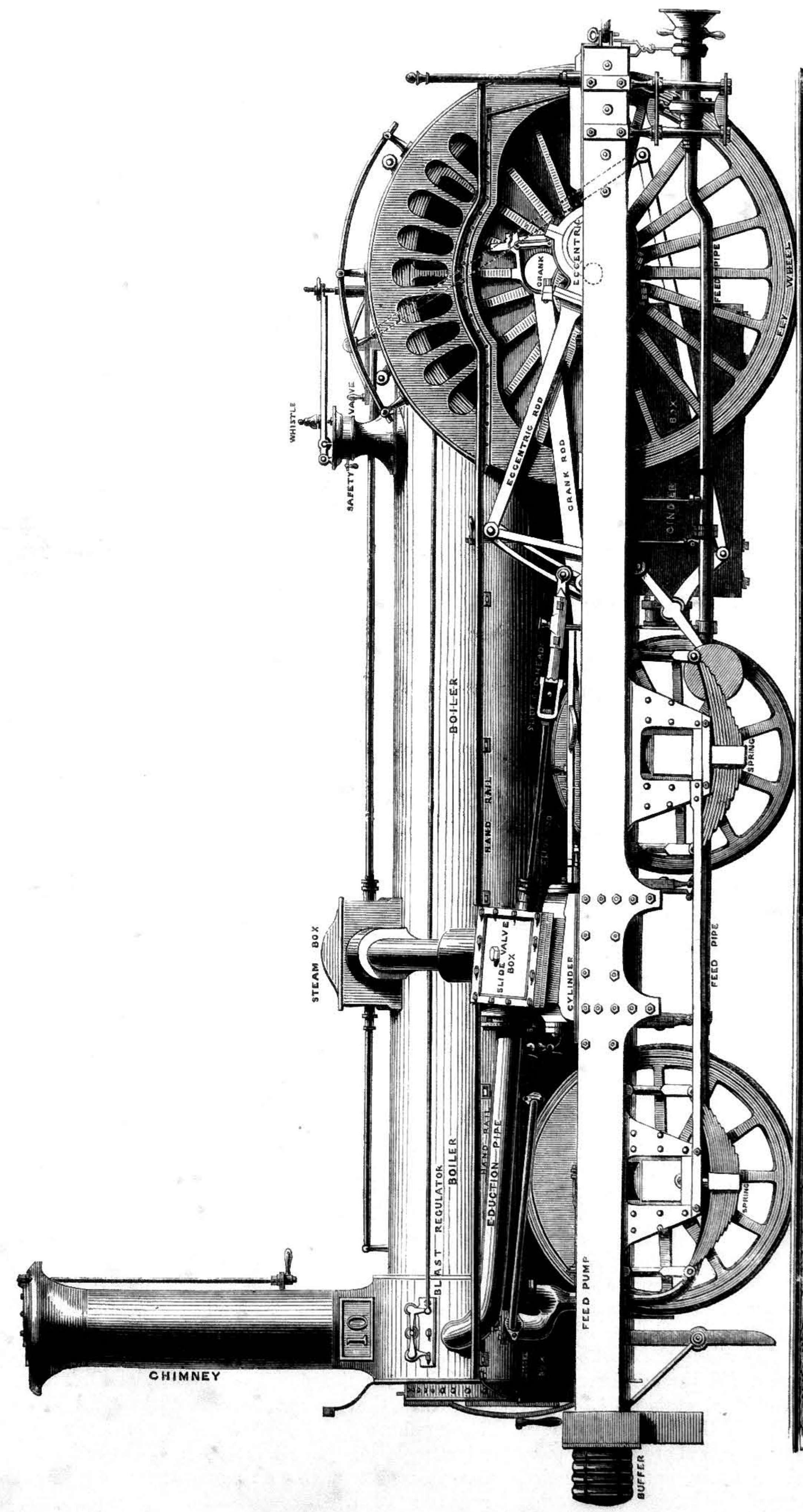


547. PRINCIPLE OF ELECTRIC TELEGRAPH.

quantity of iron ore containing carbon and manganese (called by the Germans, *Spiegeleisen*, or mirror-iron, from the circumstance of its crystallizing in brilliant tables), is melted and run in. The advantage of using this ore is that it contains a known proportion of carbon, and such a charge can be used as is just sufficient to convert the iron into steel. This being done, the blast is stopped, and the steel cast into ingots, from which rails, axles, wheel-tires, &c., are made. To give some idea of the durability of steel as compared with iron rails, a piece of railway was selected at the Chalk Farm Station of the London and North Western Railway, over which every train that left Euston Square, or arrived there, must pass. At this spot two steel rails were laid down opposite two new iron rails of the best quality. When the iron rails were worn on one face, they were taken up and turned, so as to expose the other face. It was found that 1 face of steel rails lasted while 17 faces of iron rails were destroyed, and at the time the experiment was ended, the steel face was by no means worn out. Fig. 543 represents a cross section of a few of the forms of rails in common use. *A A* are known as the *double T rail; B* is called a *bridge rail; C C* is a combination of the *T* rail with the broad base of the bridge rail. Fig. 542 represents the chair attached to the wooden sleeper, and the mode of fixing a double *T* rail in the chair by means of a wooden key or wedge driven in until the rail is firm. In dry weather the keys shrink and become loose, and require to be struck with a mallet to tighten them; but the loosening may be prevented by compressing the wood before it is inserted. This is done by exposing the keys, which are usually of oak, to steam, shaping them, and forcing them through an iron block containing holes, each $\frac{3}{16}$ths of an inch smaller than the key, and tapering so as to admit the key before compression. The keys are forced through the block by the ram of a hydrostatic press.

It would be impossible in this short notice to enter into particulars respecting the surveying, levelling, and laying out of a line of railway, so that the *gradients*, or ascents and descents, shall as nearly as possible balance each other; and in no place be so steep as to interfere with the progress of a heavy train *up* an incline, or to entail any risk of accident by its accumulating velocity *down* an incline; and so to arrange, that a train in approaching a station may gently ascend, and thus have its speed checked, and in leaving a station may descend, and have its speed accelerated. It is also important that the stuff taken out of a cutting shall be used in forming an embankment so that while, on the one hand, there is no waste of material, so also, on the other, there should not be an excess; which sometimes, nevertheless, does happen, and the company has to purchase a field or fields for the purpose of piling up whole hills of excavated material which it has no other means of disposing of. The engineer must also so arrange his line as to be within easy reach of towns and populous villages which act as feeders: at the same time the line must interfere as little as possible with the comforts, convenience, and interest of the landed proprietors, through or near whose grounds it passes. The slopes, cuttings, and embankments cannot be safely formed without much skill and varied knowledge on the part of the engineer. In stratified rocks there is a tendency of one stratum to slip upon another, and this requires the slopes to be much less steep than when unstratified materials are dealt with. This slipping is chiefly caused by the presence of water, or the action of frost between the strata; and can only be prevented by a complete system of draining, not only at the faces of the cutting, but carrying the channels backwards to collect and carry off the water that may percolate into the neighbouring soil. There must also be a complete system of surface drainage. But with all these precautions the work may have to be done more than once, and works of unexpected costliness undertaken; especially where the stratification is sand and clay alternating. When these materials are mixed, the work is safer. Stony soils, and a mixture of sand and gravel, become compact and hard. In passing through stone, the excavation may have steep sides, unless it is readily acted on by frost, and then a certain amount of flatness must be allowed. Chalk may be cut with nearly vertical faces. Slopes should be preserved by being covered with turf, or sowed with grass seeds upon a surface soil. Where a soft stratum lies under stone at the bottom of the cutting, it may be necessary to remove a portion of this, and replace it by means of walls, buttresses, arches, and inverts. The enormous quantity of material removed from some cuttings may be judged of by a few examples:—the Normanton cutting, at its greatest depth, is 55 feet: it contained 500,000 cubic yards of rock and *blue bind*—most of this was used in forming the Altoft's embankment—and 70,000 cubic yards were thrown out *to spoil*. No less than 8,600 men were employed, and there were eighteen fixed engines, working chiefly at the tunnels. When the work is apparently done, the *slipping* of the slopes would occasion much loss and trouble. Thus, in a cutting formed in the side of a hill in the north of England, it was calculated that about 50,000 cubic yards of earth would have to be removed: it happened, however, that the soft earth was upheld by a seam of shale, which, on being cut through, so large a quantity of earth slipped down into the line that 500,000 cubic yards had to be removed.

The formation of railways in so populous a country as Great Britain, where common roads are numerous, rivers and streams almost equally so, and where rights of way have to be respected, to say nothing of the undulating nature of the ground, have all contributed to the formation of numerous bridges and viaducts, some of which are noble specimens of engineering skill. It was ascertained some years ago, that for every mile of railway from two to four bridges had been built, many of them not mere single-arched bridges, but viaducts of hundreds of feet in length, and of great height, solidity, and cost. Among these the famous Britannia Tubular Bridge (fig. 538), on the line of railway from Chester to Holyhead, deserves especial notice. There are two such bridges, near together, formed of hollow girders or tubes: the first carries the railway over the river Conway; and about eighteen miles further on, the separation of the island of Anglesea from the main land of Carnarvonshire by the straits of Menai gave rise to the bolder structure, the central pier of which is based on a rock called the *Britannia rock*, which gives the name to the bridge. The necessity for such a structure was occasioned by the Lords Commissioners of the Admiralty, as conservators of the navigation, insisting that there should be a clear height of water way of not less than 105 feet under the bridge. On the Britannia rock a tower of masonry was erected; and at the clear distance of 460 feet from it, on either side, at the limits of the water way, another tower was built; while at the distance of 230 feet from each of these towers a continuous abutment of masonry, 176 feet in length, was constructed. The dimensions of the Britannia tower are 62 feet by 52 feet 5 inches at the base; while the height above high-water level is 200 feet. The stone used for the external parts is a hard and durable limestone, known as *Anglesea marble;* while the interior of the masonry is a soft red sandstone from Runcorn in Cheshire. The Anglesea and Carnarvon towers have the same dimensions at the base as the Britannia Tower, but the height is ten feet less. The abutments are terminated at the extremities of the bridge by a projecting pedestal, on which a colossal couchant lion faces the approaching visitor. The four spaces between the Britannia Tower and the other towers, and between these and the abutments, were spanned with iron tubes; and as each tube serves only for one line of rail, eight tubes were required, namely, four of 460 feet, and four of 230 feet, the four longer ones being over the water, and the four shorter ones over the land: thus each line of way is composed of four separate tubes united together, so that, in the double line of railway, there are two parallel tubes each 1,513 feet in length. To unite each of the four sections, short lengths of tube were constructed within the towers, which, being united with the main lengths, make up each complete and continuous tube. The four shorter, or land tubes, were constructed at once in their final position; but the four main tubes were built on timber platforms on the shore, and conveyed in flat-bottomed pontoons to the towers, where they were deposited,



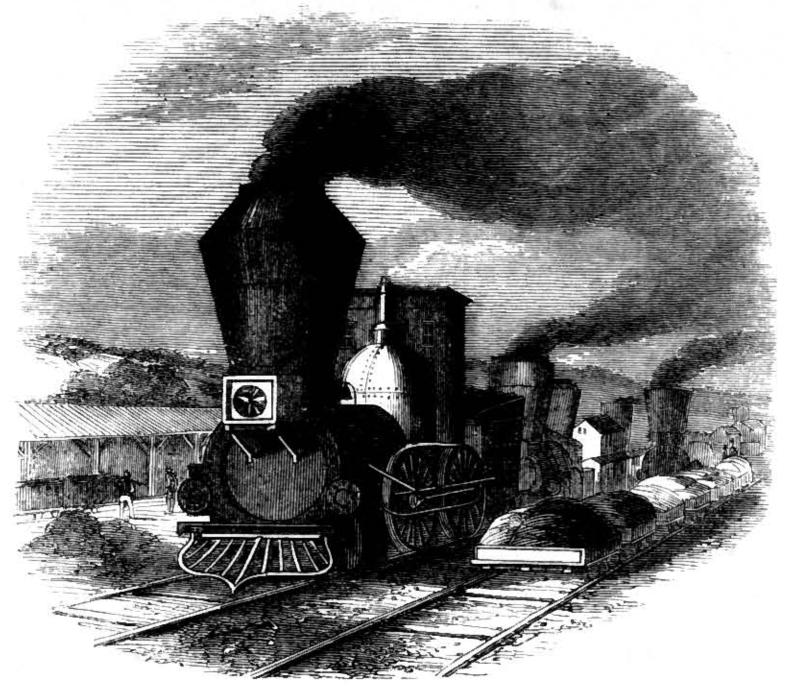
543. LOCOMOTIVE ENGINE.

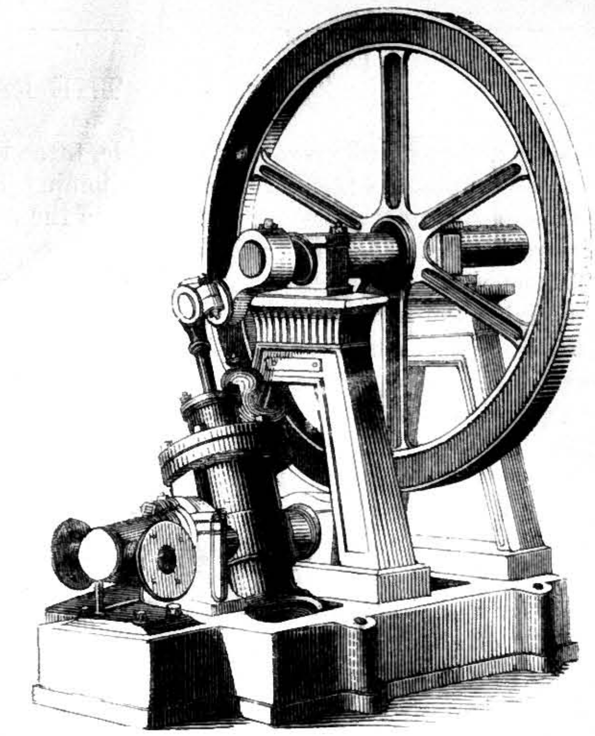
and raised into their positions by means of hydraulic presses. In this way all the scaffolding across the straits was avoided, and the channel was only interrupted during the brief period occupied in raising each tube from the base of the towers. Fig. 539 represents a cross section of one of the tubes: the sides are parallel; the height externally is 30 feet at the centre, in the Britannia Tower, and this is reduced to 22¾ feet at the extremities of the abutments; the bottom line being horizontal, while the top line forms a parabolic curve, the rise of which equals the difference in height, namely, 7 feet 3 inches. The clear internal height is 26 feet at the centre, and 18¾ feet at the ends. The external width is 14 feet 8 inches, the internal 14 feet, which is further reduced 7 inches by the ribs. The outside of the tubes consists of malleable iron plates, connected together by rivets, with ribs of *angle iron*, so called from being shaped like T and L, besides strips of flat bar-iron over the joints. The tubes are strengthened at top and bottom by means of internal longitudinal tubes or cells, of which there are eight at the top and six at the bottom. The plates vary in dimensions and thickness: those at the side are reduced in thickness from the ends towards the middle of the tube, and those at the top and bottom are increased in the same direction. The side plates are alternately 6½ feet and 8 feet 8 inches long; they are all 2 feet wide, and are arranged vertically: they are half an inch thick in the middle of the length of the tube, and ⅝ths of an inch thick at the ends. The top plates are all 6 feet in length and 1¾ feet in width. The bottom plates are 12 feet in length and 2 feet 4 inches in width; they are in two layers. All the joints of the plates are *butt-joints*, or those which meet at the edges without overlapping, the T iron being the means of holding the plates.

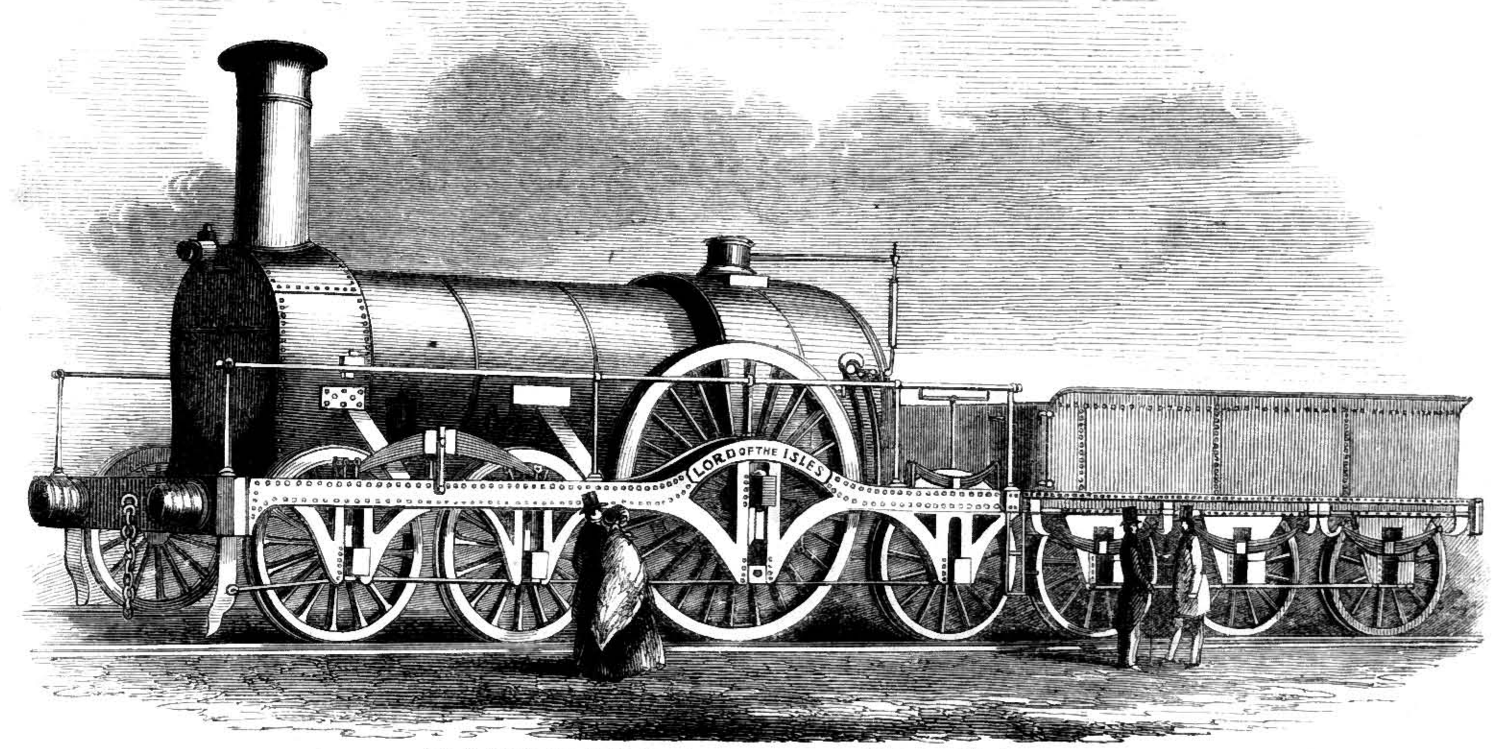
It would not be possible, without numerous drawings and elaborate description, to convey a more accurate idea of the structure of the tubes; but it may be stated, that their form was determined by the experiments of Messrs. Fairbairn and Hodgkinson, which led to the remarkable result, that with circular, elliptical, and rectangular tubes, placed horizontally, the power of wrought-iron to resist compression is much less than its power to resist tension. This is the reverse of what takes place in cast-iron, for, in cast-iron beams also placed horizontally so as to sustain a weight, the proper form is to dispose the greater portion of the material at the bottom side of the beam, whereas, with wrought-iron, the greater portion of the material should be distributed on the upper side of the beam. Hence, in the construction of the tube, it was found that rigidity and strength could be best obtained by throwing the greatest thickness of material into the upper side. It was further proved that the rectangular tube is very much stronger than the circular and elliptical form, a result which greatly assisted the mechanical arrangements, not merely for the construction, but for the permanent maintenance of the bridge.

Fig. 532 represents the railway-bridge over the Wye, in which the engineer, Mr. Brunel, introduced a modification of the tubular principle. The rails are carried upon wrought-iron girders, resting upon enormous columns of cast-iron, to the extreme margin of the navigable channel; and from this point to the opposite shore, a distance of 300 feet, the bridge is constructed, combining the principle of the tubular with the suspension. It will be seen by referring to fig. 532, that a tower or standard of cast-iron is erected upon the columns which stand in the bed of the river, and that a similar tower or standard of masonry is placed on the opposite shore. Two tubes of wrought-iron, 312 feet in length and 9 feet in diameter, are laid parallel with one another upon the summits of these towers, at the height of 100 feet above the level of high water. In fig. 533, *BB* are the columns, *EE* the cast-iron tower, *N* wrought-iron girder, carrying the end of the tubes, 1 1. Now, although we have here the main features of the Britannia Bridge,—namely, wrought-iron tubes resting with vertical pressure on piers—the roadway is not carried through the tubes, but is suspended beneath them by means of chains attached to the ends of the tube, and passing under saddles formed on the edges of the wooden platform which bears the rails. To prevent oscillation, vertical and diagonal braces are introduced between the tubes and the roadway, and, by means of adjusting screws, the chains can be stretched to any required amount. The use of the tubes is to furnish two fixed and uniformly distant points of attachment for the suspending chains, and to change their lateral pressure or tension into a vertical pressure upon the piers. In all these works where much metal is introduced, there are numerous contrivances for meeting and counteracting the unequal expansion arising from changes in temperature.

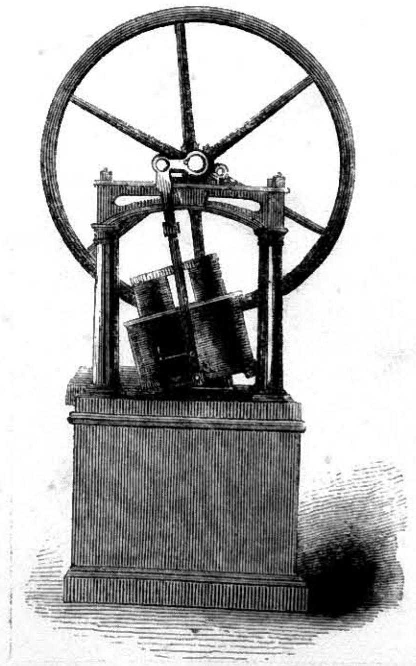
We will now give a few details respecting the roadway or *permanent way*, as it is called, in the construction of a railroad. The top surfaces of the embankments, bridges, and viaducts, and the bottoms of the cuttings, having been brought to the proper level of the line of railway, the permanent way is laid down. This includes a surface covering of ballast, in which the sleepers are imbedded. If these are placed across the railway, they carry the chairs which support the rails; but if the sleepers run in the direction of the length of the railway, the rails are bolted down upon them without the use of chairs—a piece of tarred felt or vulcanized india-rubber being interposed. The ballasting may vary from 18 to 24 inches in thickness, and may consist of burnt clay or marl, gravel, broken sandstone and lias, oolite, a mixture of chalk and flints, or of sand and broken stone, cinders or small coal, &c., depending greatly upon the materials most readily procurable. The timber used for the cross sleepers is usually prepared by *kyanizing*, or impregnating it with certain saline or metallic solutions which prevent it from rotting. In laying down the rails, their joints, end to end, must not fit so closely as to prevent the metal from expanding by heat, and contracting by cold. In a range of 76° F. a 15 feet rail will vary $\frac{1}{12}$th of an inch in length. Instances have occurred in which the rails, in consequence of butting too closely together, have been raised by the heat of the sun into ridges above the level of the rail, tearing up the sleepers and doing much damage. The distance between the rails, or the *gauge* as it is called, varies in different lines. What is called the *narrow gauge* was originally adopted in the colliery railways, and furnished the standard for the earlier lines. A 5 feet gauge was adopted on some lines, which was increased to 5 feet 6 inches, and 6 feet 2 inches in some of the Scotch and Irish lines; while, on the Great Western Railway, the *broad gauge* of 7 feet was introduced. In *laying* down the rails, provision must also be made for conducting the engines and carriages from one line to another. For this purpose, *switches* or *turn-tables* are introduced at certain points. Switches are moveable rails placed at the junction of two tracks, and may be arranged so as to guide the train from the single track into either of the two tracks, or from either of the two into the single track. The switch revolves on a pin at one end, and at the other can be made to lie close to the inside of one of the main lines of rail, or retire a few inches from it. In fact, the switch is merely a continuation of a line of railway which diverges from the main line, and makes a small angle with it, and becomes connected, by a similar switch at the other end, with the parallel line of rails, or with the branch line, or with the siding. Fig. 531 represents a simple form of the switch, and its action will be understood by inspection. The short rail slightly bent, fixed opposite to the points, and near to the inner side of the other rail, requires some explanation. Of course the wheels of the locomotive and carriages are retained upon the rails by the flanges or ribs projecting from them. If, in approaching a switch, the flange of the wheel were either too near to the rail, or too far from it, it might either fail to catch the point of the switch, or might catch it when not intended to do so. The short bent rail, called the *guide-rail*, prevents this; for, by acting on the flange of the opposite wheel, it draws the carriage over into the position most favourable for catching the points. These guide-rails occur wherever two lines of railway intersect each other, requiring the rail to be cut or divided. The turn-table is a contrivance for moving a single carriage at a time from one line of rails to another. It consists of a circular platform, usually of iron, supported on rollers, and turning on a centre without much friction, even when heavily loaded. In transferring a carriage from one line

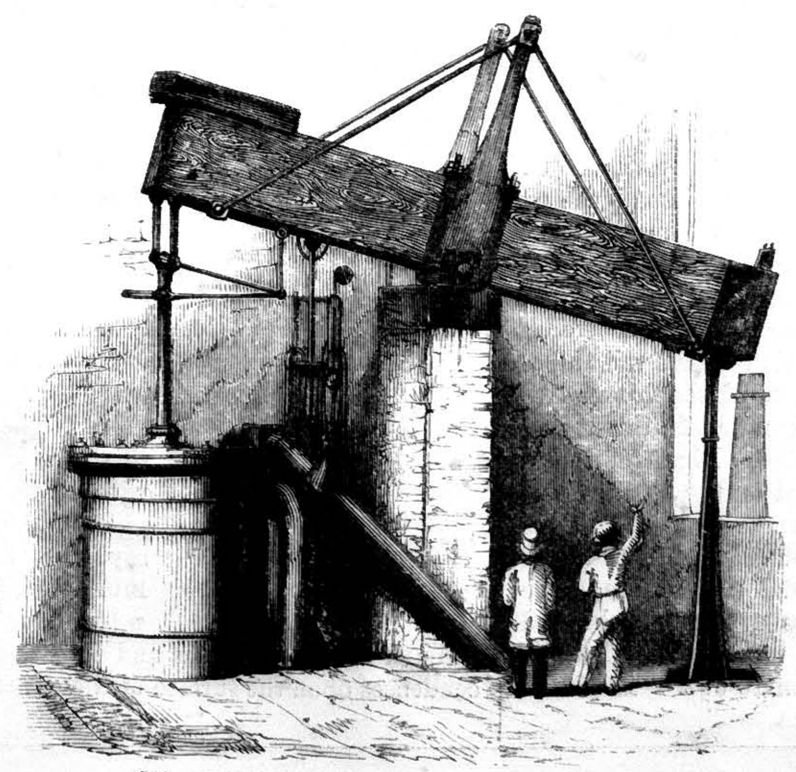

549. AMERICAN TANK ENGINE.

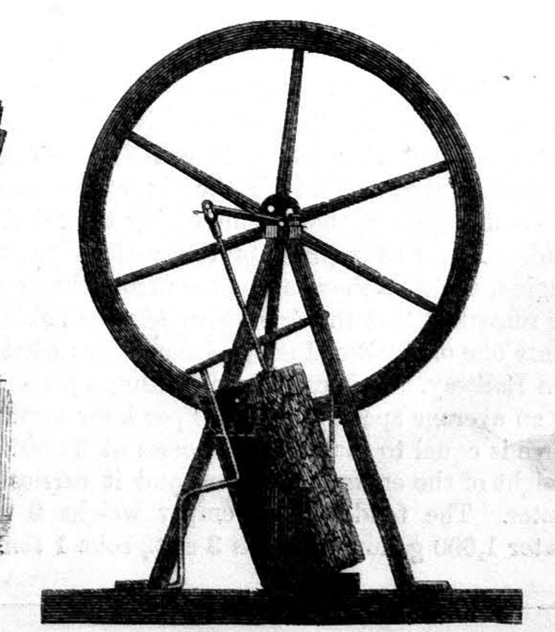

550. PRINCIPLE OF OSCILLATING ENGINE.



548.* LORD OF THE ISLES LOCOMOTIVE. (*Swindon Works.*)


551. MAGNETIC OSCILLATING ENGINE.

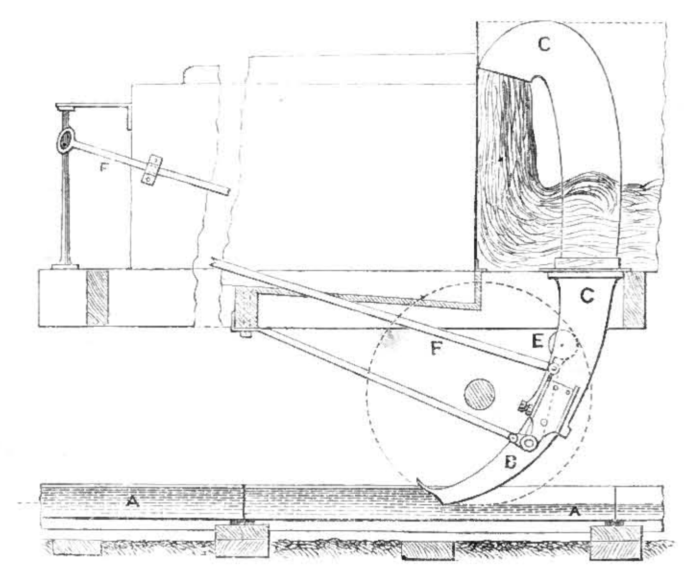

552. AN ORIGINAL BOULTON AND WATT ENGINE.


553. MODEL OF OSCILLATING ENGINE. (*Date* 1784.)

to another, it is rolled upon the turn-table, turned a quarter round, then rolled upon the turn-table of the adjoining line, and being, in like manner, turned a quarter round, it is in the proper position for being rolled upon the new track.

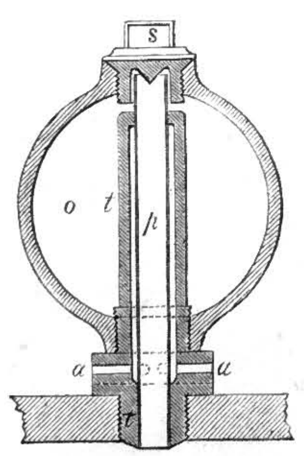
The enormous capabilities for traffic of a railway depend chiefly on applying the power of steam to the drawing of wheel carriages. The idea seems to have originated with a Cornish engineer, named Trevithick, who, with his partner, Vivian, took out a patent in 1802, for a steam-engine adapted for propelling vehicles on common roads. In 1804, one of these engines was tried on a Welsh tram-road with satisfactory results. It was, however, imagined that the friction between the road and the smooth iron tire of the wheels would not be sufficient to produce attractive power, and engineers actually constructed engines with iron legs or propellers, armed with short spikes, for taking hold of the road (fig. 528). These legs had a step or stride of about 26 inches, and were made to abut alternately against the ground, by the reciprocating action of a steam-piston and cylinder. Another contrivance was a toothed rack, or series of cogs extending along the road; and a toothed wheel, worked by the steam-engine, was engaged in this rack. Experience, however, showed that the mere rolling friction of a smooth wheel against a smooth rail, exerted sufficient traction for all ordinary purposes; except, indeed, sometimes in ascending inclines, or when in certain states of the weather the rails are slippery, it is necessary to scatter sand on the rails, to increase the friction. Many attempts had been made to use steam carriages on common roads, but the jolting caused by rough broken stones was found to loosen the joints, and disarrange the parts on which the working of the steam apparatus depends. These, and many other considerations, determined the directors of the Liverpool and Manchester Railway Company to place, if possible, locomotive engines on their lines. Accordingly, in April 1829, a premium was offered for the best locomotive engine, capable of drawing three times its own weight, at the rate of 10 miles an hour: its weight, when filled with water, was not to exceed 6 tons, and it was not to cost more than 550*l.* It is strange to contrast this modest proposal with results which have since been realized. We now see every day engines which, with their tenders, weigh 30 tons, drawing immense loads, at speeds varying from 20 to 60 miles an hour, and costing 2,200*l.* each. In the competition above referred to, the prize of 500*l.* was awarded to Robert Stephenson, for his engine the *Rocket* (fig. 530), in which it will be seen that the cylinders (that on one side being shown in the figure) are placed diagonally, and act directly on a pin attached to one of the spokes of the wheel. So successful was this engine, that although 10 miles an hour had been fixed as the limit of speed, yet, within a very few months after the opening of the line, the journey of 31 miles from Manchester to Liverpool, was performed in one hour, and at the present day it is not unusual for a train to move at the rate of 50 or 60 miles an hour. One of the modern forms of locomotive is represented in fig. 535. It is mounted on six wheels, which do not revolve independently on their axles, as in common road vehicles, but are secured immoveably in pairs, upon shafts or axles, which support the weight of the boiler and engines on brass bearings. Of these three pairs of wheels, the centre pair only is *driven* or acted on by the power of the steam-engine. Engines which are built for goods traffic, usually have their driving-wheels united by *coupling-rods* with the other two pair, which must consequently be of the same diameter, so that all the six wheels are made to revolve by the motive power, thereby increasing the friction on the rail three-fold. Fig. 548 represents the various parts of the locomotive engine, so far as they can be seen from the exterior. In this it will be remarked that the driving-wheels are behind. Fig. 548* represents one of the broad gauge locomotives used on the Great Western Railway. It is capable of taking a passenger train of 120 tons at an average speed of 60 miles per hour upon easy gradients. Its force is equal to that of 1000 horses at 33,000 lbs. per horse. The weight of the engine is 31 tons, and it carries 4 tons of coke and water. The tender when empty weighs 9 tons, and its load of water 1,600 gallons=7 tons 3 cwt., coke 1 ton 10 cwt. The heating surfaces are, fire-box, 156 feet; 305 tubes, 1,759 feet; diameter of cylinder, 18 inches; length of stroke, 24 inches; diameter of driving-wheel, 8 feet; maximum pressure of steam, 120 lbs. The actual consumption of fuel, with an average load of 90 tons, and an average speed of 29 miles, is nearly 21 lbs. of coke per mile. Contrasted with this fine engine is the ugly-looking *Tank Engine*, used in the United States of America (fig. 549). This engine carries its own coke or wood, and water, so that there is no tender. In some cases the water is held in semicircular cisterns, placed above the boiler, and the fuel in a space near the fire-box. These engines carry sufficient fuel to run light passenger trains at high velocities on short journeys. The number of sparks given off when wood is used as the fuel, leads to the necessity of covering the chimney with a wide conical case with wire gauze stretching across it inside. In front of the engine is an arrangement called a *cow-catcher*, for removing cows, sheep, and other obstacles from the road.

The carriages, &c., of a railway are called the *rolling stock*, and of this the locomotive is the most important. It is being constantly improved by the introduction of new details. Thus, Mr. Ramsbottom has introduced into the tender of some of his fast engines a kind of scoop, which being let down into a trough of water placed between the rails at certain points of the road, the impetus of the train forces up the water into the tank without stopping the train.



SCOOP FOR SUPPLYING THE TENDER WITH WATER.

Thus the scoop *B*, the orifice of which is 10 inches wide, when let down is immersed 2 inches in the water, which entering it is forced up the pipe *C C* into the tank. The upper end of the pipe is turned at the top to prevent the water from splashing over. The scoop turns on a bearing, and, when not in use, a weight at *E* tilts it up so as to clear the ground. At *F* is a handle by which the scoop is let down into the water *A*. There is also an ingenious kind of self-acting lubricator introduced for oiling the valves, &c. It is so arranged that a small quantity of steam is admitted from time to time into a tube over the valve where the lubricator is placed, and the steam condensing into water sinks to the bottom of the oil vessel, thus causing some of the oil to overflow and lubricate the part required. The following section will explain this. *O* is the oil vessel, which is filled with oil up to the level of the top of the pipe *p*, the lower end of which opens, say, into the cylinder which is to be lubricated. Steam ascends up the pipe *p* (which is kept cool by cold air rushing through the channel *a a* and into the space between *t* and *p*) and condenses upon the surface of the oil. The water thus formed sinks



SELF-ACTING LUBRICATOR.

to the bottom of the vessel *O*, and causes a small portion of oil to overflow into the pipe *p*, which descends into the cylinder and lubricates the piston. In this way a minute quantity of oil descends with every stroke of the piston. When all the oil has thus been displaced by water, the screw-stop *s* is removed, the water drawn out by means of a syphon, fresh oil poured in, and the stop replaced. The apparatus is modified a little for the lubrication of valves, &c. Each vessel contains about a week's supply of oil.

Coal is now taking the place of coke in locomotives, and this has led to several reconstructions of the furnace. In some cases the grate bars are arranged in the form of steps, so that the flame and hot gases may be reflected on and gradually meet the fresh fuel as it descends from the hopper. Air is admitted to the place where the coal first begins to distil, and other air is admitted through the bars, the object being to burn the smoke and volatile products as fast as they are formed.

Locomotives have also been constructed for very steep gradients. In one case the engine has two pairs of *horizontal*, as well as two pairs of vertical, driving wheels; while a *third* rail introduced between the ordinary bearing rails is acted on by the horizontal driving wheels of the engine. In this way sufficient adhesion between the wheels and the rails is obtained. A road has been constructed over Mont Cenis on this principle, while waiting for the completion of the tunnel, eight miles in length, through the mountain.

Improvements have also been made in *traction-engines*, or locomotives for common roads. The wheel tires are made very broad, and the engines travel slowly. Those used by farmers are constructed so as to lay down their own roads as they move along. This is done by means of broad timber planks attached to the wheels—shoes or pattens of iron or steel have also been proposed.

Railway post-office vans under the management of the Post-office authorities are placed on our railways for the purpose of facilitating the sorting and delivering of letters, &c. Bags can be given out and taken in while the train is in full motion.

With respect to the railway carriages little need be said, except to point out the use of the *buffers*,—namely, for preventing those sudden jerks, and even accidents, which would arise if the carriages were not brought very gradually to rest. Fig. 537 represents the under part of a railway carriage, with the body removed. The round knobs, or disks of the buffers, are fixed on sliding bars, the other ends of which are connected with powerful springs secured to the bed of the carriage. When the motion of the carriage receives any check, these springs receive the shock and by their elasticity destroy or absorb it. In a similar manner jerks are avoided by attaching each carriage to its predecessor or to the engine, by means of a hook formed upon the end of a bar, which slides through sockets and is connected with the middle of a stout spring, the ends of which are fixed. On applying the motive power to the engine, its momentum is first communicated to these springs, by which means the carriage is not suddenly and rudely, but gradually, set in motion. The buffers and draw-bars also tend greatly to diminish the lateral or rolling motion of the carriage. The carriages are not simply connected by chains, but are linked one to another by a little apparatus in which the power of the screw is brought into operation. The coupling-links consist of two oblong loops of iron, one end of each of which is formed into a nut for the reception of an iron bar, having a screw cut on the greater part of its length. The thread of this screw is so arranged, that on turning the bar, the two loops approach each other: and a lever, terminated by a heavy ball, is connected with the middle of the bar for the purpose of turning it round. The links of this apparatus being slipped over the hooks on the draw-bars of two adjacent carriages, the screw is turned until the buffers are not only in close contact, but are in some degree compressed by the force applied; and the friction between the faces of the two pairs of buffers will be sufficient to prevent, or at least to check, the tendency of each carriage to roll or oscillate laterally, independent of the other. The whole train thus becomes a continuous line, flexible indeed, but sufficiently rigid to secure a steady and uniform forward motion: the efficacy of the contrivance is sufficiently proved by the ease with which the small type of a newspaper can be read in a railway carriage. Whenever a rolling or lateral motion is perceived, it may generally be checked by turning the screw of the coupling-links.

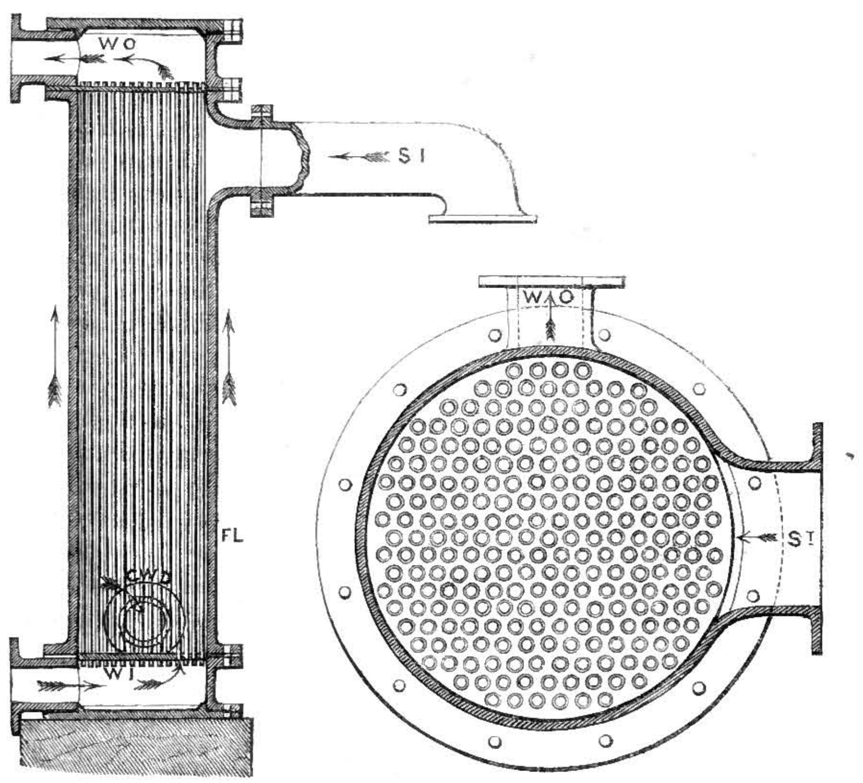
The *breaks* are contrivances for stopping the train. They consist of blocks of wood (commonly willow), forced strongly against the peripheries of the wheels by a system of leverage. The tender is provided with a powerful set of these breaks; the guard's van has another; and the joint operation of these brings the train to a stand at the desired spot. When the sudden appearance of danger requires a very energetic application of the breaks, the driver assists their action by *reversing* his engine, that is, by causing the wheels to revolve in the direction opposite to that of its progress. These combined forces, however, occasionally fail to prevent collisions, when foggy weather or other causes have prevented the usual warnings from being given. The porters at a station facilitate the stoppage of the trains in moist weather by throwing a little sand upon the rails.

Most of the large railway companies do their own engineering work. The workshops of the London and North Western Railway Company, at Crewe, cover 17 acres of ground. Here there is a rolling mill for the manufacture of permanent-way rails, and the yield of finished rails is about 15,000 tons per annum. There are also engine works for the construction and repair of the locomotive stock of the line; there are fifteen steam hammers of from 6 to 50 cwt.; and they have lately introduced Mr. Ramsbottom's duplex, or double-headed or horizontal, steam hammer, in which the ingot or other work is forged between two hammer-heads working horizontally, thus getting rid of the heavy foundations and destructive vibrations of the ordinary vertical hammer. There are upwards of 100 smiths' hearths, about 20 of which are employed in wheel-making alone. The erecting shop is 240 ft. long and 80 wide, and is capable of accommodating 24 of the largest class of engines. The repairing shops have a total area of 5,800 square yards, with standing room for upwards of 70 large engines. They turn out at Crewe 100 new engines every year, and keep in repair about 1,400 engines. There are also tender, joiner, and pattern shops, and the works are connected by a tramway about half a mile long, and served by a small locomotive engine named *Tiny*. This engine traverses curves of 15 ft. radius each with loads of from 12 to 15 tons, and will take 7½ wheel forgings or tires on edge by means of trucks adapted for the purpose; it has 4 wheels coupled, inside cylinders 4¼ in. diameter and 6 in. stroke. The wheels are 15 in. in diameter on a base of 3 ft. The total heating surface is about 42 square feet; the boiler is fitted with a No. 2 Giffard's injector, and carries a saddle tank capable of holding 28 gallons. The total weight in working order is 2½ tons. A second engine of similar construction, named *Pet*, has also been introduced.

Connected with the railway system is the Electric Telegraph, which we can merely glance at in this place. It may be sufficient to remark that when a stream of electricity from a galvanic battery is conveyed along a wire, near which a magnetic needle, poised on a pivot, is placed, the needle will tend to take up a position at right angles to the wire, according to certain laws. Thus in fig. 547, let *A B* represent the wire, and *C D* a magnetic needle placed on a pivot so as to revolve freely; on transmitting a current of electricity along the wire, the needle will tend to leave its parallel position and take up another position at right angles to the wire. Now, every magnetic needle has two poles,—namely, a north pole and a south pole, and these poles take up a position east and west, or west and east, according to the mode in which the wire is arranged, whether above or below the magnetic needle, and according as the current is made to flow from left to right, or right to left. Now it will easily be seen that if a needle be arranged at each end of the line, so as to connect both needles with each other and with the battery by means of a wire suspended by means of posts between the two stations, it would be easy to arrange a code of signals, by means of which a message could be forwarded from one station to another. For example, suppose the needle to be mounted vertically on a dial, like a clock with a single hand. If the needle point to XII. it may signify 0, if it be made to move to I. it shall mean *a*, if to XI. *e*, if to II. *i*, if to X. *o*, if to III. *u*. If made to move twice to I. it may mean *b*, if twice to XI. *c*, and so on; and as the motions of the needle at one station are accurately repeated at the other station, we may easily imagine how they are transformed into intelligible language. If the wire which conveys the message be properly guarded it may even be laid along the bed of the ocean, and continue in constant use, as is the case with the numerous lines which diverge from this country to various parts of the world.

The application of steam to navigation has produced results almost equal to those of land travelling. Steam vessels of enormous size have been contrived, by means of which, long voyages are reduced to short ones, and the uncertainties which once arose from contrary winds are got rid of.

The various parts of a marine-engine are arranged with a view to compactness, as will be seen by reference to figs. 541, 546. The reader is aware that the object of this machinery is to give motion to two large wheels, called *paddle-wheels* (fig. 546), which dip into the water, and by the reaction of the float-boards against it, which act like oars, give motion to the ship. The paddle-wheels are connected with a massive iron rod, called the *paddle-shaft*, which derives its motion by means of a crank attached to the beam and connecting-rod of a steam cylinder and piston. In a stationary engine, the beam and connecting-rod, which oscillates between the steam cylinder at one end, and the fly-wheel at the other, are placed above the steam cylinder, whereas, in the marine engine, the beam is placed below it. The beam, parallel motion, and connecting-rod are similar to those of a stationary engine, only they are turned upside down; and as the beam cannot be placed directly over the piston-rod, two beams and two systems of parallel motion are provided, one on each side of the engine, acted on by, and acting on, the piston and cranks, and conveying motion to the paddle-shaft by means of cross-pieces which project beyond the sides of the cylinder. Fig. 527 represents a section of a marine-engine, in which *X* are sleepers of oak for supporting the engine, *U* the *furnace*, the shaded portion round it being the boiler, *i* is the *flue*, *l* the *steam-chest*, *S* the *steam-pipe*, *C C* are *slides* which open and shut by the motion of an eccentric placed on the *paddle-shaft*, and through these slides the steam is admitted from the steam-pipe to the top and bottom of the cylinder. *A* is the *cylinder*, *B* the *condenser*, and contains cold water for condensing the steam when it has served its purpose in raising or lowering the piston, when it is drawn off by *E*, the *air-pump*, which also discharges the water arising from the condensation of the steam; this water is conveyed into *F*, the *hot-well*, from which the boiler is renewed. *T T* is the *feed-pipe* for conveying the water, *L* is the *piston* connected by the parallel motion to the *beam H*, which works on a centre near the base of the engine. The other end of the beam drives the *connecting-rod*, *M*, which extends upwards and works with cranks. The dotted lines show the beam on the further side of the engine; a similar beam similarly placed, and working on the same centre, must be understood to be on this side connected with the piston. *Y* is the *safety-valve*, *Q R* the framing by which the engine is supported, *h h* are cocks for pouring off salt water from the boiler. The salt in sea-water forms a sediment in the boiler, which not only diminishes the heat, wastes the fuel, and entails risk of explosion, but corrodes the iron, so that it is necessary from time to time to blow out the salt. To prevent these inconveniences, what are called *surface condensers* are introduced for the purpose of condensing the steam (which would otherwise escape to waste) into fresh water, and using this for feeding the boiler. Surface condensers usually consist of a number of tubes surrounded by running cold water, which of course may be salt, and the steam entering the tubes becomes condensed into fresh water. This method of using the water over and over again is useful in the case of land engines placed at a distance from rivers, canals, and wells. The boiler can be supplied with as much pure distilled water as is required, thus preventing incrustation. It is found in practice, however, that pure water cannot be used in the boiler, because some of the oil used in lubricating, getting into the boiler, becomes converted into acid grease, which attacks



SURFACE CONDENSER.

the metal-work. To prevent this a few lumps of chalk are put into the boiler to combine with the oil. A useful form of surface condenser by Mr. E. A. Cowper is shown in the preceding figures, in which cold water is made to pass up the tubes in a quick current, so as to brush off as far as possible the numerous air bubbles which cling to the heated surface, and injure its effect. The steam to be condensed is admitted into the space outside these tubes, and condenses upon the surfaces kept cold by water running through the tubes. In both figures *S I* represents the steam inlet, *W I* the water inlet. The water passing in the direction of the arrows through the tubes, escapes by the water outlet, *W O*. In the meantime, the steam entering by the channel, *S I*, condenses into water, which escapes by the condensed water outlet, *C W D*.

Another great improvement in the steam-engine is an arrangement for super-heating the steam before it enters the engine. Low pressure steam seems to be mixed with a good deal of spray or partially condensed steam; and the action of the super-heating apparatus is to dry it, and thus greatly to increase its volume and elasticity without much increase of temperature. In this way the steam within the cylinder is not so readily condensed, so that it is capable of doing more work, and producing a saving of fuel to the amount of 10 per cent. Super-heaters consist in principle of a bundle of tubes placed in the passage through which the hot smoke passes from the furnace to the chimney. The steam is generally sent through the tubes, and the smoke through the channels between them, but in some cases the tubes are made to transmit the smoke.

In what are called *oscillating* engines, the beam is got rid of, and power is saved by getting a more direct action. In this form there are two cylinders which move backwards and forwards by the action of the crank on the piston; that is to say, the piston, as it rises and falls, causes a revolution of the crank, which in its turn moves the piston and cylinder backwards and forwards. There is a fixed air-pump between the cylinders. There is also a pump connected with the machinery for supplying the boiler with water from the sea, so long as the engine is working; and when the vessel is stopped for any length of time, a smaller engine, called a *donkey*, is set to work to keep the boiler full. The screw, fig. 524, is now usually

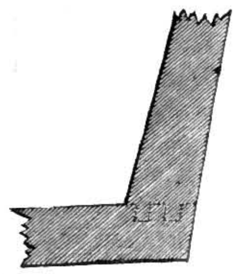
preferred to paddle-wheels. The screw consists of a shaft turned round by the steam-engine, but differently placed, for it projects from the stern in a line with the keel of the ship: the vanes, which extend from it obliquely, in turning in the water, strike against it in such a way as to force the ship forward.

The principle of the Oscillating Engine is represented in fig. 550. It is one of the simplest examples of a direct rotatory action obtained from the combination of the piston-rod and the crank. The idea is by no means a new one, as was noticed at the time of the Great Exhibition of 1851, with reference to the model (fig. 553), which was made by Murdoch in 1784 for the purpose of illustrating Watt's patent for making the cylinder work on its axis. Fig. 551 is an Oscillating Engine in which, instead of the cylinder and piston worked by steam oscillating, we have an electro-magnet, consisting of two hollow cylinders of soft iron, surrounded by coils of wire, in which two pistons of soft iron work, also surrounded with coils of wire, forming a second electro-magnet. When the current from a galvanic battery is passed through the wires, the cylinders and the pistons attract each other with considerable force. The pistons are attached to a crank on the driving shaft by means of a connecting-rod, and the magnetic cylinders are made to oscillate at each stroke by a contrivance for making and unmaking the magnets on either side of the axis alternately. There have been numerous proposals for working machinery and driving locomotives by means of electro-magnetic power. There are, however, many objections to it, and so long as coal is plentiful it will probably be found more economical to employ it directly in raising steam, than indirectly in smelting zinc, which has to be consumed in the galvanic battery.

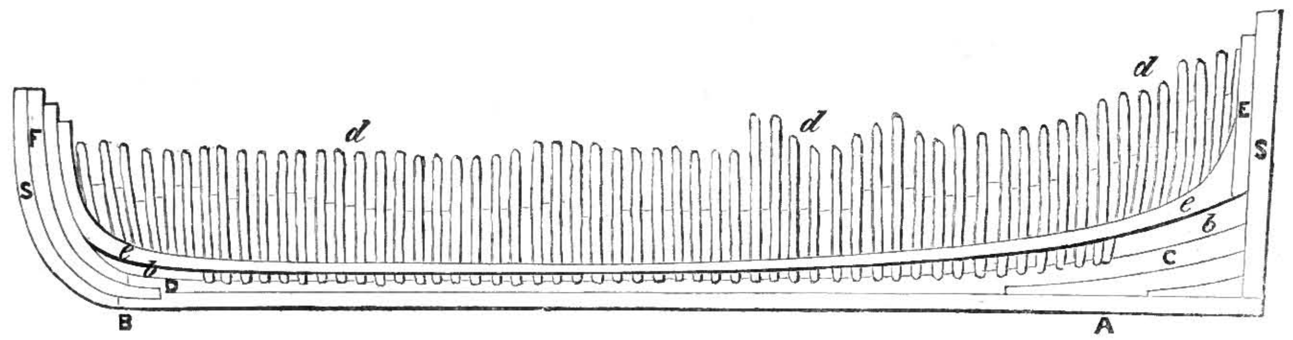
XXVIII.—THE SHIPWRIGHT.

A LARGE number of trades is concerned in the building and finishing of a ship; but the man who shapes and puts the timbers together is called a *shipwright*, and of him we shall chiefly speak. Ship-building is both a science and an art: it is a science, inasmuch as some of the grand principles of nature are brought to bear upon the form of the vessel, and the positions and proportions of its various parts, such as will best promote stability in the water, and speed in moving through it, &c. Ship-building is an art, inasmuch as it depends on certain rules of construction, which are subject to variation according to experience or the peculiar notions of the naval architect. Then, again, the mode in which a ship is built depends greatly on the kind of service she has to perform. A man-of-war is always furnished with the same kind of stores, whereas the lading of a merchant-ship is liable to frequent variation; the cargo may be heavy at one time, and comparatively light at another. With a heavy cargo the ship may be immersed two or more feet deeper in the water than with a lighter one; and the draught of water in a collier may vary at different times as much as 4, 5, or 6 feet. As the ship becomes lightened she loses in stability, and may acquire a dangerous rolling motion. These and many other causes render the theory of ship-building complex and difficult. We do not intend to refer to them except to remark, that the architect, having carefully decided as to the form and dimensions of the ship with reference to its special object, draws three plans, or sections in planes, passing through the largest portions of the ship, and known as the *sheer plan*, the *half-breadth plan*, and the *body-plan*. The sheer plan divides the ship into two equal parts, by a plane passing through the middle line of the vessel, from the middle line of the stem or fore-boundary, to the middle line of the stern-post or after-boundary. The half-breadth plan describes half the widest and longest level section in the ship, or that of a horizontal plane, passing through the length of the ship, at the height of the greatest breadth. The body plan describes the largest vertical section athwart the ship. The drawings are usually on a scale of $\frac{1}{4}$ inch to 1 foot, and when they are all settled and agreed on, enlarged copies are made to the full size of the objects represented, and they are traced with chalk on the floor of a room, called the *mould loft*. This is called *laying-off*, and its object is to furnish the workmen with the exact shape and proper positions of the principal pieces of timber of the intended ship. The floor is usually equal to half the length of the ship, and the whole height of the hull in addition. When the plan is laid down, the timber ribs or *frames* are marked in their proper places, and pieces of plank $\frac{3}{4}$ inch thick are cut to the forms of the timber; these are called *moulds*, and are used as patterns for cutting or converting the timber, certain marks made on the moulds indicating the directions in which the sides of the timbers are to be cut.

The ship is usually built on a piece of ground called the *building slip*, forming an inclined plane towards the water into which the ship is to be launched. The first thing to be done is to arrange on the slip a row of oak-blocks, 3 feet high and 4 feet apart, in the direction of the length of the intended ship. On these blocks is laid the *keel A B*, fig. 555; it is the lowest timber of the ship, and upon it the whole fabric is raised: the wood is usually of elm, which resists the water well, and its fibres are sufficiently tough to receive the numerous fastenings and bolts which pass through it. The keel usually consists of a number of pieces of timber scarfed together. Below the main keel, which in a large ship may be 20 inches square, pieces of elm from 4 to 6 inches thick are worked, forming what is called the *false keel*, the object of which is to give the ship greater immersion, and in the event of her grounding in shallow water, the false keel by being forced off may free the ship from danger. At each end of the keel, and extending towards its middle, timbers called the *dead-wood* are placed as at *C D*; and the upper surface is cut into a curved form, *b b*, with which line the bottom of the ship's body is made to coincide. At each end of the keel is set up a post; that at *S* being the *stern-post*, and that at *S'* the *stem-post*: the latter is curved near the bottom. In large ships the stem is made up of 3 pieces; called the *upper*, *middle*, and *lower* pieces: they are united to each other and to the fore-end of the keel by means of scarfs, or with coaks and copper bolts; the scarf which unites the stern with the keel, being termed the *boxing*. The stern-post should be of oak, and if possible in one piece, on account of its having to support the rudder; the mode of inserting the keel of the stern-post in the after-piece of the keel by means of tenons and mortices, is shown in fig. 554. The ribs or *frame* of the ship form a collection of timbers; such as *floors*, *cross-pieces*, *futtocks*, and *top-timbers*. The sides and upper portion of the keel and dead-wood are cut for the reception of the floor timbers, which are placed across the keel, as shown in section *a*, *b*, *c*, *d*, fig. 557, *e*, *f*, being the middle line of the ship; and in order to keep it steady in crossing the keel, a piece of timber called the *rising-wood*, *g*, *h*, *i*, *k*, is worked into the seat of the floor and into the keel. In some cases the floor is steadied by means of a coak, passed both into the floor and into the keel, as at *e*. For the sake of economy the frame is sometimes arranged as in fig. 558; in which two *half floors* meet



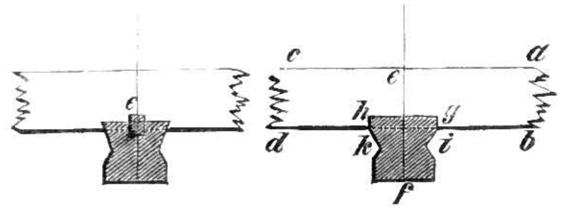
554. INSERTION OF STERN POST IN KEEL.



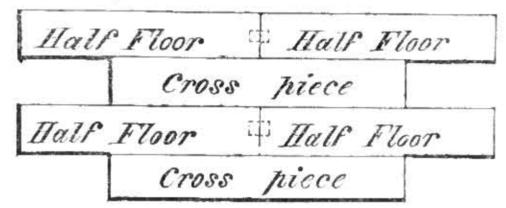
555. ELEVATION OF SHIP'S TIMBERS.

555*. THREADS OF OAKUM.

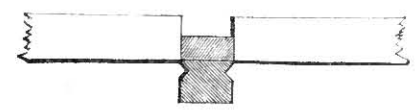
556. MALL.



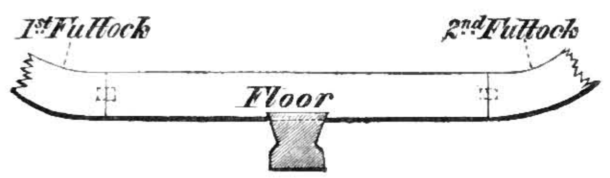
557. FLOORS, TIMBERS, AND KEEL.



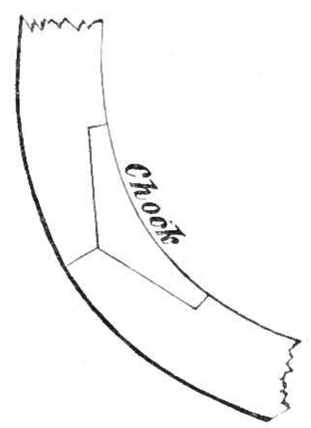
558. ARRANGEMENT OF FLOOR TIMBERS.



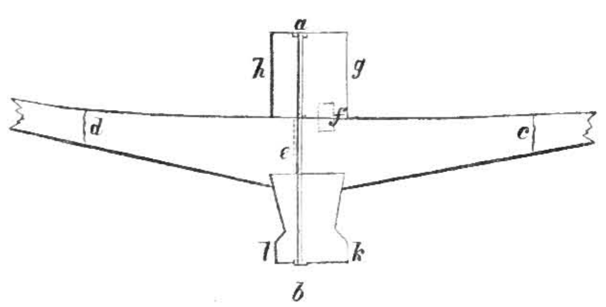
559. FUTTOCKS AND DEAD-WOOD.



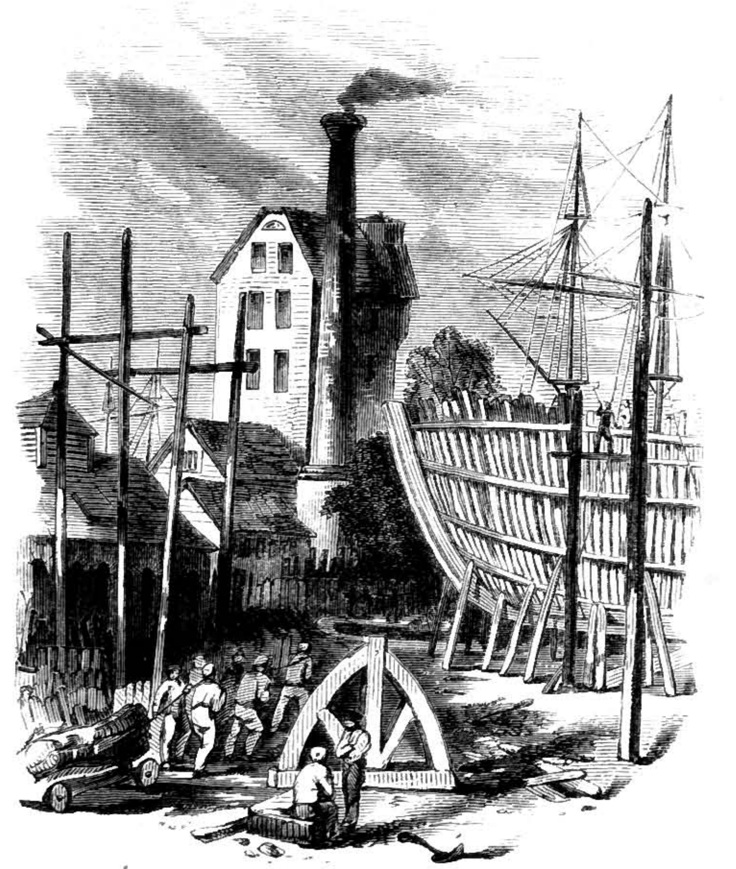
560. CONNEXION OF FLOOR WITH FUTTOCKS.



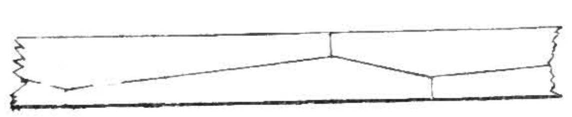
561. UNITING TIMBERS WITH CHOCKS.



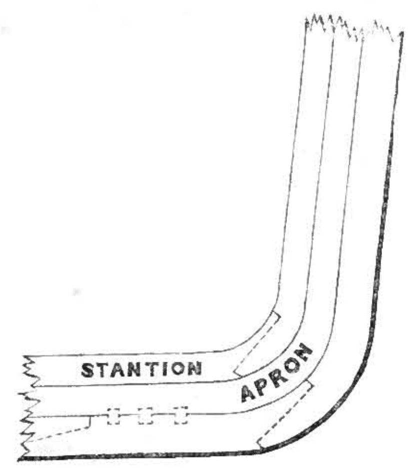
562. FLOOR TIMBERS, KEELSON, AND KEEL.



563*. SHIP YARD.

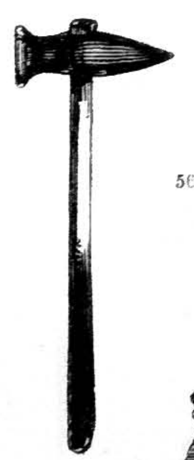


563. ARRANGING PLANKS, TOP AND BUTT.



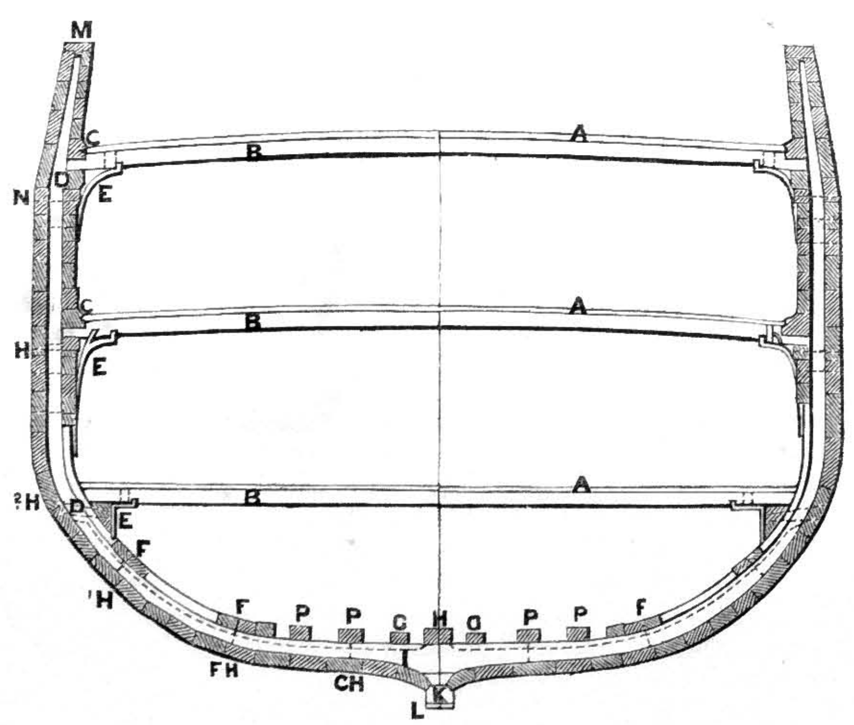
564. POSITION OF APRON.

564*. COPPERING-HAMMER.



564**. MALLET.

565. PITCH POT.



566. MIDSHIP SECTION.

566*. CAULKING.

in the middle of the vessel, and alternate with *short floors* or cross pieces. The timbers which join the cross pieces or floors are called the *first futtocks*, dowels or tenons of hard wood being placed in the heads and heels of the respective pieces, as in fig. 560. In merchant ships the first futtocks run down to the side of the rising wood or dead-wood, so as to leave what is called a *water-course* of the breadth of the keel or of the rising wood, as in fig. 559. The *second futtocks* are placed on the heads of the half floors, and the *third futtocks* on the heads of the *first futtocks*, the *fourth* on the heads of the *second*, and the *fifth* on the heads of the *third*: the *top timbers* are placed on the heads of the *fourth timbers*, and these, with the top timbers and *lengthening timbers*, form the frame. In merchant ships the heads and heels of consecutive timbers are united by means of *chocks*, as in fig. 561, which economise the timber.

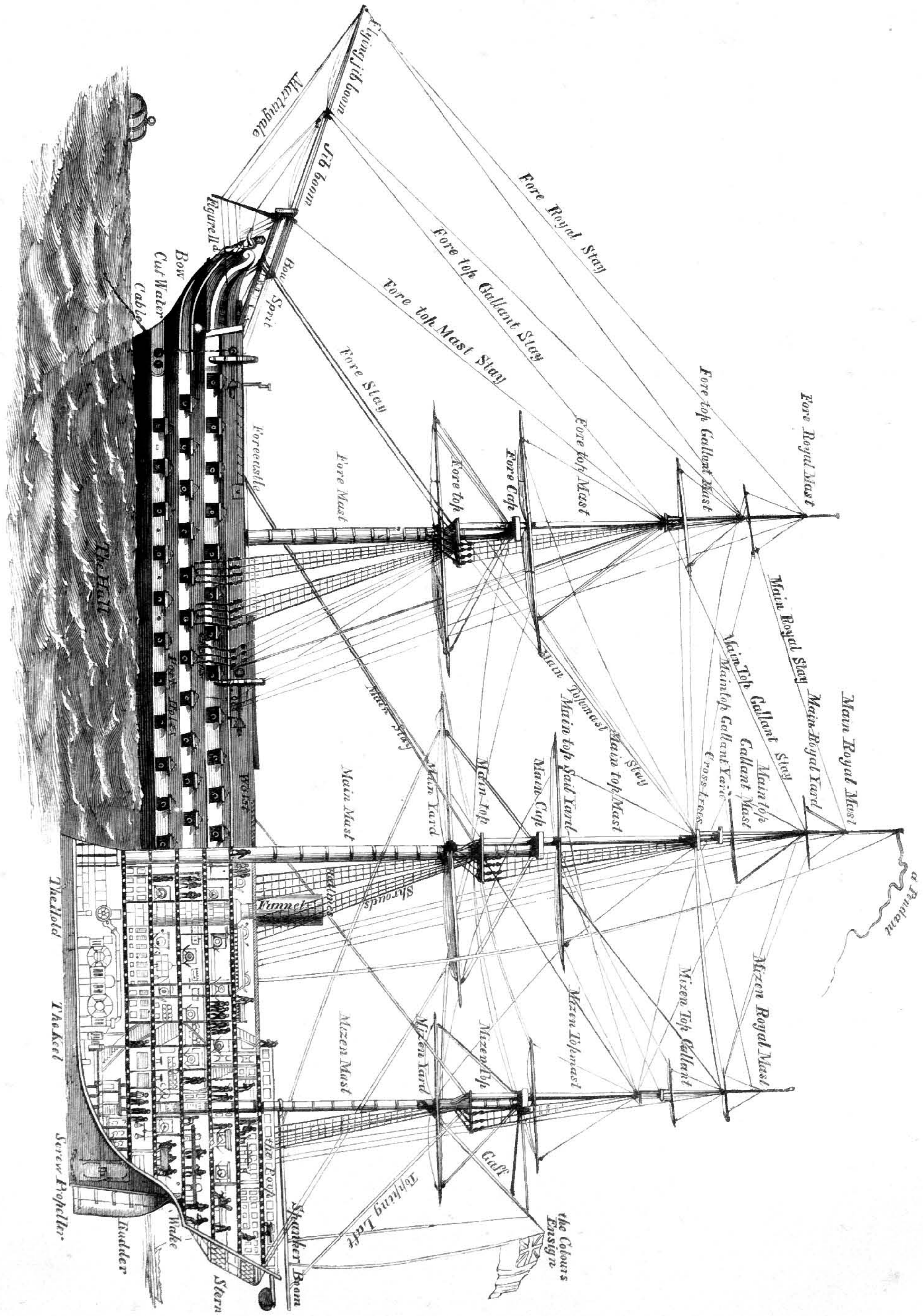
The distance between the frame timbers varies in the Royal Navy from 2 ft. 6 in. to 2 ft. 9 in. The timbers above the surface of the water are nearly straight, but below it they are of various curvatures to suit the form of the ship. Within the stem is a timber called the *apron*, fig. 564: it is a continuation of the fore dead-wood, as the stem is a prolongation of the keel. Its use is to strengthen the stem, and allow for the reception of the plank of the bottom, and the heels of the foremost timbers. In order further to support the stem, the *stemson*, fig. 555, is worked in. The inner post is a continuation of the after dead-wood, and forms a foundation for the reception of the plank, and receives the heels of the extreme after timbers. The floor-timbers are secured in their places by the *keelson*, fig. 562, which is square in form, and of the same width as the keel, *k*, *l*; *c d* are the heads of the cross-piece, *e* the butt joint of the half-floors, placed on one side of the middle line to allow a coak *f* to be inserted clear of the butt *e*, and the copper keelson bolt *a b* is passed also on one side of the middle line, through the keelson, cross-piece, and keel. In large ships two additional keelsons, *G G* fig. 566, called *side* or *sister keelsons*, from 30 to 50 feet long, are bolted to the floor-timbers, sufficiently near to one another for allowing the *step* or foot of the main-mast to rest upon them.

The timbers are covered on the outside and partly on the inside with planks of oak from 3 to 6 inches thick, secured by means of bolts and trenails, or plugs of oak. Before the planking is applied, the spaces between the frame timbers are filled up with pieces of wood 3 inches deep, and the spaces between the exterior and interior pieces are sometimes filled up with cement, so that should the outside planking be torn off the vessel would still float. There is a tendency, after the vessel has been some time in the water, for the keel to become curved, in consequence of the falling of the extremes and the rising of the middle of the ship. This *hogging*, as it is called, has been met by a diagonal framing or trussing, and also by introducing iron plates, for tying the timbers to each other.

Fig. 566 represents a mid-ship section, in which *A A* represent the *decks* or *platforms*, *B B* the *ship's beams*, *C C water-ways*, *D shelf-pieces*, *E iron knees*, *F strakes*, *F H*, *I H*, &c., *heads* and *heels* of the frames, *G limber strakes*, *H keelson*, *I fillings* between the timbers of the frame, *K keel*, *L false keel*, *M rough trenail*, *N wales* or *thickest planking*, *P P bearers* for the boilers of a steam vessel. The beams *B* which receive the decks of the ship, are supported at their ends on longitudinal ribs called *shelves*, which form portions of the internal planking of the frame. In order to apply the planking or *skinning* as it is called, the frame is set perpendicular by dropping a plumbline from certain points to the middle line of the ship. That part of the skinning called *bends* or *wales* is commonly of English oak called *thick stuff*, and varies from 4½ to 10 inches in thickness. To make up this thickness the planks are worked *top and butt*, fig. 563, to suit the tapering shape of the timber, the lower or butt end of one plank being brought to the top of the upper or thinner end of another plank. The planks are not fixed at once to the frame, but are hung thereto with the holes bored, and are so left in order that the air may dry up the juices of the wood; the fastenings are wooden trenails or copperbolts. The first band of inner planking from the keelson is called the *limber strakes*, *G* fig. 566, but a space is left between the side of the keelson and the lower edge of the strakes, which serves as a gutter for drainage. The gutter is protected from the dirt of the hold by limber boards or plates when of iron, otherwise the dirt might pass into the pump-well and choke the pumps. A large ship has usually three strakes on each side; next to the strakes are the planks *F*, which are worked over the heads of the floor timbers and the heads of the first futtocks to prevent these timbers from being forced in. The beams may be compared to the rafters of a house, supporting as they do the floors or decks; they are not flat, but set to a *round*, or portion of a large circle, so that the decks when placed on them may throw off the water to the sides, where holes called *scuppers* are placed to convey it away. The inside planking immediately under the shelves is called the *clamps*, and that over the water-ways the *spirketting*, the latter being so secured by dowelling as to prevent the beam ends from rising off the shelf pieces, when the ship is rolling in a sea-way. Next comes the framing of the deck, in arranging which provision must be made for doorways, hatches, and mast-holes. These last are of larger diameter than the masts by double the thickness of the wedge which holds the masts in position. The framing for a mast-hole with wedges consists of *fore and aft partners*, *cross partners*, and *corner chocks*. The hatchways or doorways from one deck to the other are formed of four pieces, the two placed fore and aft being called *combings*, and those athwart ship, *head ledges*. These last rest on the beams, and the combings have pieces of wood called *carlings* under them and extending from beam to beam. The ladder-ways are framed in a similar manner, and on the upper deck are skylights, or framings for the *galley* or cooking range similarly worked. The framing of the ship also includes the *riding bitts* in the fore, for receiving the cable when the ship is riding at anchor. The *ports* or oblong holes in the sides in which the guns are worked are closed in stormy weather by *port-lids*, which are hung with hinges on the upper side and held up by ring bolts, a piece of glass being let into them to give light when closed.

The joints or seams of the outer planking are made water-tight by means of spun threads or layers of oakum forced into them, for which purpose the seams of the planking may be opened by sharp iron wedges called *reeming irons*. The oakum is driven into the joints by means of *caulking irons*, which are also sharp iron wedges. The seams are next *payed* with melted pitch applied with small mops, and that part of the ship which is to receive the copper sheathing is levelled by laying in spun yarn and *payed up*, or covered over with a mixture of pitch and tar. The decks of the ship are also caulked with oakum, and the weather decks are payed with marine glue.

The ship being now made water-tight is ready for launching. It has already been stated that the slip-way on which the ship is built is inclined towards the water, but in order that she may be slid down into her own element without damage, the weight of the ship (which in a large man-of-war may be as much as 2,600 tons for the hull alone) is transferred from the slip-blocks to a supporting framework or *cradle*. This cradle is formed upon two inclined planes or *sliding ways*, one on either side of the keel. The cradle is supported by what are called *bilge ways*, while the sliding ways are blocks of wood supporting planks so as to form an inclined plane. Outside the bilge ways, and to prevent them from being forced out by the weight of the ship, is a timber called a *riband*, and this forms the abutment of the after end of a piece of timber called the *dog-shore*, the fore-end of which butts against large *cleats* on the bilge ways, and these cleats retain the ship on the sliding ways until everything is ready for launching. Thus the bilge ways form the support of the cradle, and the cradle is the truck or carriage which bears the ship into the water, while the sliding ways are the inclined planes down which the bilge ways move. The amount of inclination to be given to the sliding ways is determined by the size of the ship, the rise and fall of the tide, and the inclination of the building slip. The slide beyond the slip is laid during the recess of the tide, and a number of other arrangements having been made, the upper sides



567. NAMES OF THE VARIOUS PARTS OF A SHIP.

of the sliding ways and the under sides of the bilge ways are payed over with melted tallow; and when this is cold, soft soap or oil is added in patches. The bilge ways are then turned in, and the cradle is adjusted to the bottom of the ship, when, on the morning of the launch, large wedges called *slices* are placed inside and outside the bilge ways, and men with heavy hammers are stationed near them. By driving in these wedges the hull is raised in the cradle, and its weight taken off from the blocks on which the after part of the vessel rested during the building. The blocks are then removed. The forepart of the cradle is not attached very firmly to the bottom of the ship, but the weight rests partly on the foremost building blocks, which just before the launching are split out from under the ship, so that just before high water she is seen from aft, supported on two comparatively narrow ribands. The ship is christened by dashing wine against her bows or forepart, and the signal "down dog-shore" being given, the last obstruction is removed, the ship glides into the water, the cradle falling from her and rising in loose detached pieces to the surface.

The launching is a good test as to the soundness of the naked planking. The next process is *sheathing*, for which purpose the ship is floated at high water into dock, and being placed on the blocks prepared for her, the dock gates are closed, and the water at the fall of the tide is let out through drains or culverts. The ship is secured by means of *guy ropes*, and by shores of timber, extending from the sides of the dock to those of the ship. The copper sheathing is in sheets, 4 ft. by 14 in.; while the thickness is indicated by the weights of the square foot, which vary from 32 oz. to 16 oz. In applying the sheathing, the lower edges of the upper sheets are made to lap over the upper edges of those below, and the after end of each sheet to lap over the fore end of the one following it. The 32 oz. copper sheathing is used round the ship at the height of the load water line for four *strakes* or sheets down, and on the bows down to the keel. The 18 oz. and 16 oz. sheathings are usually placed between the main and false keels, to protect the former from the worm should the latter be torn off. A 120-gun ship requires 4,444 sheets of copper for the sheathing. The copper is liable to constant corrosion from the action of sea-water; but it may be protected by using zinc-headed nails in fastening it on, when a voltaic current is formed, and the zinc is dissolved in preference to the copper.

A ship's mast is usually formed of several pieces: the central piece is in the form of a many-sided prism, and other pieces are attached to its sides by means of a projection in each, which is let into a corresponding channel in the central piece, or blocks of hard wood may be let into the central and the attached pieces, the whole being secured by iron hoops placed at intervals. The masts resist the pressure of the wind by means of *shrouds* and *backstays*, which are secured to the sides of the ship. The foremast is usually set upright, but the main or mizen-masts *rake*, or incline aft.

The large collection of ropes used for supporting the masts and for extending or reducing the sails, are comprehended in the general term *rigging*. This may consist of *standing rigging*, such as *shrouds*, *stays*, and *backstays*, used for supporting the masts, and occupying a fixed position in the ship; while the *running rigging*, including *braces*, *sheets*, *halliards*, *clue lines*, &c., is used for arranging the sails, and is passed through various blocks, arranged about the masts, yards, shrouds, &c. The *lower rigging* is used for the lower masts, and the *topmast rigging* includes the topmast shrouds, stays, and backstays.

The arrangement of the masts and rigging for the most part determines the class of vessel. Thus a *ship* has a *fore*, a *main*, and a *mizen* mast, with a *topmast* and a *top gallant mast* to each, while the yards in sailing before the wind are braced *square;* that is, in horizontal positions perpendicular to the length of the ship. When the mizen mast carries no top sail, or top gallant sail, we have a *barque*. A *brig* has no mizen-mast; a *schooner* has two masts but no top sails, and the sails are in vertical planes, passing through the keel. A *sloop* or *shallop* has only one mast with a mainsail, the plane of which is usually in a fore and aft position. All these varieties have each a *bowsprit*, carrying a *fore staysail*, and a *jib sail*. A *line of battle ship* carries 70 or more guns. A *frigate* has usually two decks, and carries from 36 to 60 guns. Sloops and corvettes carry from 4 to 20 guns; brigs, cutters, brigantines, ketches, schooners, and barques, do not carry more than 10 guns each.

Vessels are now frequently constructed of iron: they are formed with ribbed frames at intervals, and with longitudinal hoops of iron, and they are covered with iron plates attached to the ribs by means of bolts and rivets. The lower part of the interior is sometimes divided into separate air-tight compartments, so that, should the bottom be pierced in any one part, the water would be confined to that compartment.

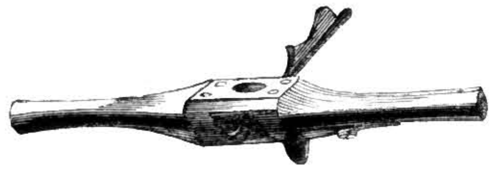
As a ship of war usually indicates its size by the number of its guns, so a merchant ship shows its size by its tonnage; a term which really refers to the number of tons of sea-water which a vessel would contain. Now as there are 35 cubic feet of sea-water in a ton weight, the interior volume of a ship expressed in cubic feet divided by 35, gives the tonnage. But as the ship when she floats in still water, with only her equipments and stores on board, occupies a plane passing through the ship at the level of the water, and known as the *light-water plane*, and as this differs from a similar horizontal plane passing through the ship when laden, and known as the *load-water plane*, the volume of that part of the ship between the two planes, expressed in cubic feet, and divided by 35, gives the weight of the ship's cargo.

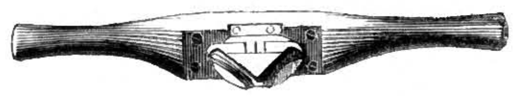
The foregoing details will give some idea of the complicated structure of a ship. Should the reader desire further information, he will find it in a cheap and accessible form in the Rudimentary Treatises on Naval Architecture by Mr. Peake, Assistant Master Shipwright of H.M. Dockyard, Woolwich: we would especially refer to Parts II. and III. of this work, published separately, containing the "Practice of Ship-building."

XXIX.—THE COACHMAKER.

If the various descriptions of craft used for conveying people over seas and rivers be numerous, so that it requires a special study to acquire their names and leading characteristics, not less varied are the wagons, coaches, and vehicles used for land-carriage. To say nothing of sledges, sedans, palanquins, and litters, which preceded the introduction of the wheel, there are carts with solid wheels, or slices cut off from the trunk of a large tree; carts and wagons of wood bound with hide, and a flooring of the same material; carts tilted with canes and straw neatly wattled. We may next notice improvements in the wheel, the introduction of springs for hanging the carriage and diminishing concussion, and the introduction of two additional wheels with facilities for turning the vehicle. To trace all these varieties, and the improvements which have been from time to time introduced, would require a very long history; whereas all we propose to do is to give a few details respecting the trade of the coachmaker, and these must be imperfect, seeing how greatly the trade is subdivided, for in building a coach we have to consult the *coach-body-maker*, the *carriage-maker*, the *coach-smith*, the *coach-plater*, the *coach-beader*, the *coach-carver*, the *coach-trimmer*, the *coach-lace-maker*, the *coach-lamp-maker*, the *harness-maker*, the *coach-wheelwright*, the *coach-painter*, the *herald-painter*, and some others.

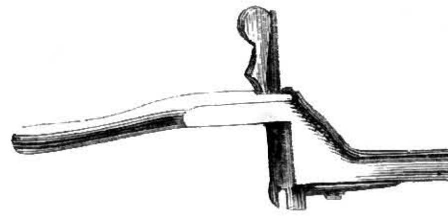
The materials used in a coach, are timber, iron, plated metal, leather, woven materials, paint, varnish, &c. The first operation in


569. GROOVING ROWTER.

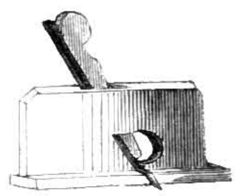

571. SIDE ROWTER.

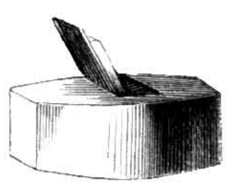

568. GIMLET.

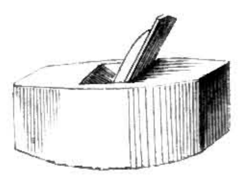

570. SPOKESHAVE.

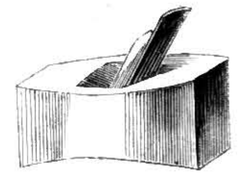

572. PISTOL ROWTER.

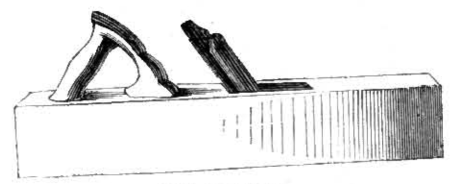

573. DRAW PIN.

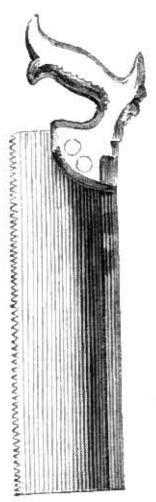

574. PLANE.

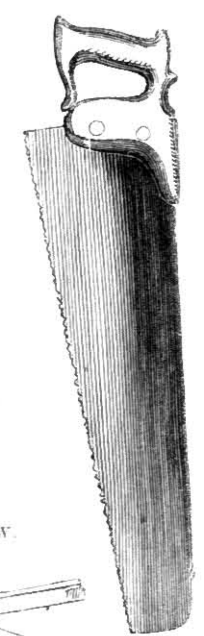

575. HAND PLANE.

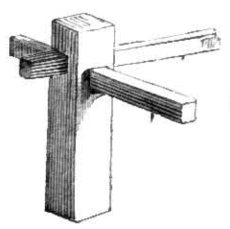

576. CONVEX PLANE.

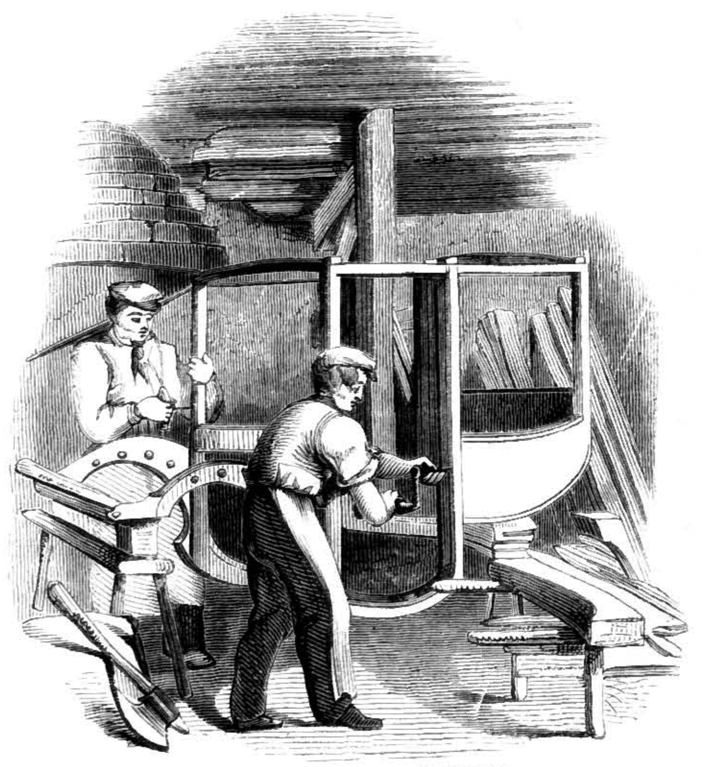

577. CONCAVE PLANE.

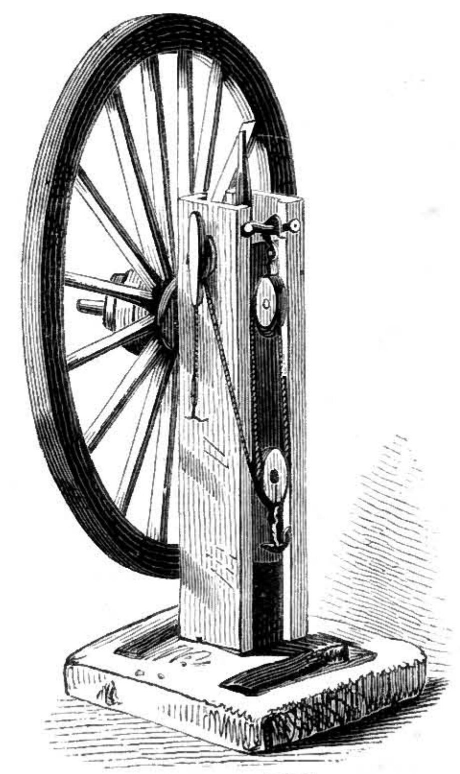

578. PLANE.


579. TENON SAW.


580. HAND SAW.

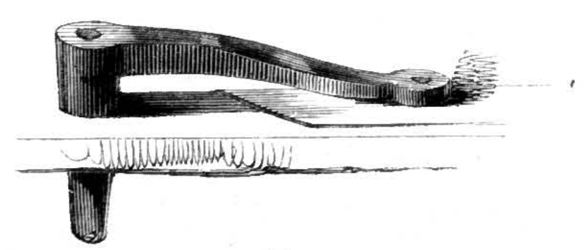

581. GAUGE.


582. COACH-BODY MAKERS AT WORK.


583. WHEEL HORSE.

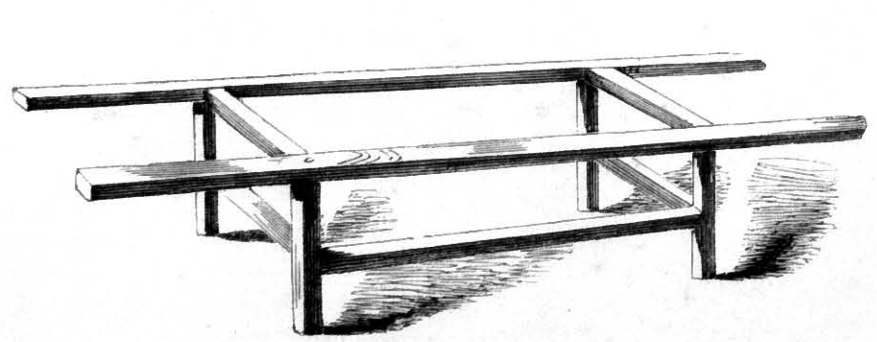

584. CHISEL.


585. GOUGE.


586. HOLDFAST.


587. SQUARE.


588. SIDE AXE AND CHIPPING BLOCK.


589. HORSE.


590. PAINT BRUSHES.


591. PAINT-POT.

building a coach is to make a design, such as will show the forms and proportions of the various parts, the arrangements made for the comfort and convenience of the traveller, and the general effect of the whole. Thus the designer is to a certain extent an artist, and as new forms and fashions are constantly arising, there is usually a certain constant amount of work for him. He has also to make the working drawings, which are sketched on a black board on the same scale as the work to be executed. The mode of proceeding then very much resembles the plan adopted in ship-building, where, as already stated, *moulds* are formed in thin pieces of wood, for directing the shipwright in his work. In like manner, the *mould* of a coach is prepared by cutting out a number of thin pieces of wood according to the chalk marks on the board, to serve as a guide to the workman in cutting out the timbers, and this is the more necessary, since all the lines of a coach are curved, and many of the curves have a complex character.

The timber having been selected, it is cut up at the saw pit, first in the round, and afterwards for *converting;* that is, it is first cut into planks, and then roughly cut at another pit into the forms indicated by the pattern pieces. The most valuable wood used by the coach-builder is hedge-row ash, well adapted for the frame-work on account of its tough fibrous character, and its not being liable to warp. Beech is not used in the best coaches; elm is used for planking and also for the naves of wheels, and oak is preferred for the spokes of wheels and for those parts which require to be strong and durable. The panels are formed of Honduras mahogany, and sometimes of cedar, while deal and pine are also used in the floor and roofing, and a few other kinds of wood, such as fustick, lance-wood, birch, sycamore, chestnut, and plane, are employed to a limited extent.

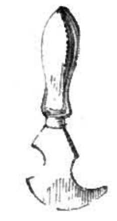
The coach-builder applies the term *carriage* to the frame-work which lies beneath or around the body, and serves to support it, and to connect it with the wheels, pole, &c., so that there are two distinct sets of workmen, one known as *body-makers*, who construct the frame-work and panelling, &c., and the other as *carriage makers*, whose work is rougher. The pieces of the frame-work of ash having been cut to shape, are put together for the body; and as the meeting edges are seldom at right angles to each other, the joints are made by means of glue, bolts, nails, screws, tenon and mortice, lap-joints and grooves; constantly referring to the mould-pieces in executing the work. There is not much peculiarity in the tools, for they resemble those of the joiner. It will be seen, however, that the *planes* (figs. 576, 577) are adapted to convex and concave surfaces. There are also various forms of *rowters* (figs. 569, 571, 572), or planes for forming grooves, for levelling the bottoms of cavities, &c. The *spoke-shave* (fig. 570) is a small plane iron something like a penknife, set in the middle of a frame which can be used with both hands. It works easily in the direction of the grain, and is used for shaping and smoothing small rounded surfaces. The curved form is given to the panels by wetting the wood on one side and heating it on the other.

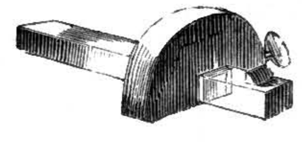
When the various parts of the body have been put together, and the carver has added the beadings and mouldings required, a thick coat of paint is laid on; but before this, for the best work, the roof and a portion of the sides, front and back, are covered with leather, for which purpose a large sound hide is selected, and having been well soaked it is thrown over the top and rubbed or pressed down on the roof, until it lies perfectly smooth and even. The workman then takes one of the hanging pieces and rubs it flat to one of the sides, trimming it off at a beading which separates the panels from the quarters or upper panels. He proceeds in like manner with the other parts, flattening the surface without making any incision in the skin; for this would be liable to let in the wet and ruin the carriage: by means of skilful rubbing and working, he is able to get rid of the folds or wrinkles at the corners; by working the leather gradually from these corners towards the centre of the sides and back, the puckers disappear, and the leather tightly adjusts itself to the form of the body. When the leather is properly adjusted, the painter sets to work, and it is a long business before he completes it, as many as from twelve to fifteen coats being applied. There are from six to eight coatings of copal varnish, and the result is as beautiful and durable a polish as can be met with in any kind of wood-work.

It is scarcely necessary to do more than refer to the fine Spanish cloths, the rich plain and embossed silks, the embossed leather, the lace, and the cushions employed in finishing the interior of a coach. The lace may be of worsted or of silk, or of both materials combined, and it is used as a binding or edging: what is called *pasting lace* is used for concealing rows of tacks, and *seaming lace* for concealing seams and edges. The roof, sides, and other parts of the interior are made level by means of wadding and canvas, and are lined with cloth or silk. Cushions are stuffed with horsehair, and covered with cloth, silk, or morocco leather. The bottom of the coach and the folding steps are covered with carpet.

While the coach-body makers are at work upon the body, the carriage makers are engaged on their part of the structure. The springs have to be formed, either as *single elbow springs, double elbow springs, under springs, nut-cracker springs, C springs, S springs*, &c.; while the smith has to form various pieces of iron-work, such as *plates, loops, stays, hoops, clips, bolts, steps, treads, joints, jacks, shackles*, &c.; some of which, however, belong to the body. The making of the wheels constitutes the distinct trade of the wheelwright. A wheel consists of a centre or *nave*, radii or *spokes*, and a circumference or the *felloes*. The nave is a short block of elm pierced with a hole for receiving the axle-tree: the spokes are rods of oak radiating from the nave, while the felloes are circular segments of ash, attached to the ends of the spokes, and uniting so as to form a circle: the felloes are all bound together by an iron hoop or *tire*. The nave is brought to shape in a turning lathe, and having been pierced for the axle, the mortices are chiselled out for the ends of the spokes. The mortices must be cut with great care, so as to give the spokes, or rather the wheel, a *dishing* as it is called, or slight concavity on the outer surface, so as to give more room for the coach body, and to avoid the splashing about of wet mud. The oak for the spokes is cut into lengths of four feet, which are then shaped by hand. The spokes are driven into the nave by means of a mallet, the nave being placed for the purpose in a kind of socket in the floor. This is called *speeching* or *spoking*. The felloes being properly shaped by means of pattern boards and cutting tools, are drilled each with four holes; two for receiving the cylindrical ends of the spokes and two for joining the felloes, end to end, by means of dowels of oak. After this, the whole is bound firmly together by means of a solid iron hoop, which is put on at a red heat, and well beaten, while it is being rapidly cooled by water poured upon it. The tire in cooling contracts in dimensions and holds the frame-work tightly. Iron pins are driven through the tire and felloes one on each side of every joint, and the points are riveted inside the felloes. The projecting parts of the nave are also furnished with iron hoops for the sake of strength. The axle consists of three parts; namely, the two *arms* which pass into the naves of the wheels, and the *bed* or central part which connects them together. The nave is lined with a well-fitting iron box for receiving the axle with little friction, and also for containing a reservoir of oil. The axle is usually turned at a lathe, and is then case-hardened, that is,—its surface is converted into steel. White metal, or *albata*, or white brass, is largely employed for beading, plates, locks, hinges, handles, rings, buckles, &c., but iron plated with thin sheet brass is also used. A good deal of the semi-cylindrical beading is made by drawing sheet metal through an iron or steel plate, and the concave side of the beading is afterwards filled in with soft metal and is furnished with points for fixing it. For the best work the beading is formed of sheet copper, coated with silver.


592. ROUND KNIFE.

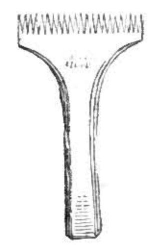

593. HEAD KNIFE.


594. CUTTING GAUGE.

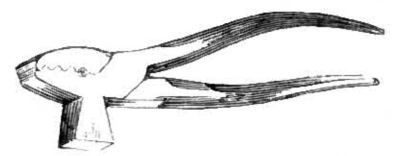

595. DEAD PUNCH.


596. HAND KNIFE.


597. SPOKESHAVE.


599. PRICKING IRON.


600. COMPASSES.

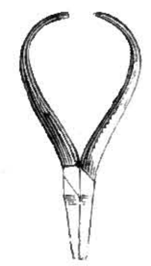

603. PINCERS.


604. PUNCH.

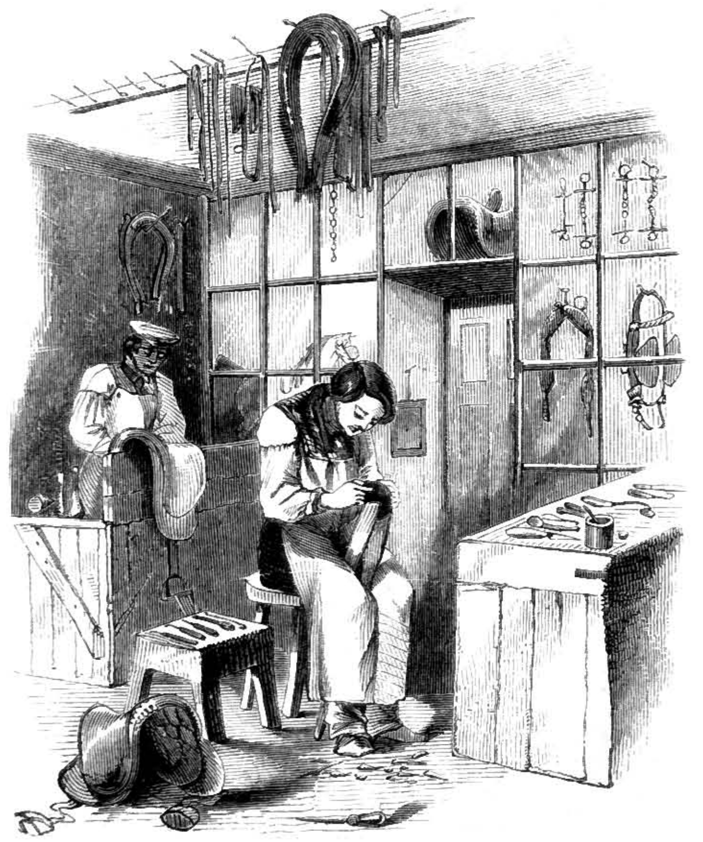

601. EDGING IRON.

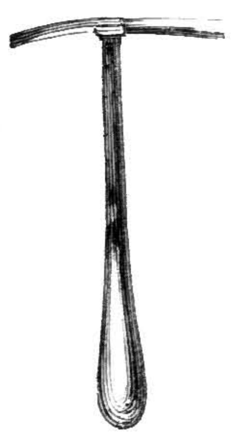

602. SEWING AWL.


605. SCREW CREASE.


606. PLIERS.


611. CLAMPS.

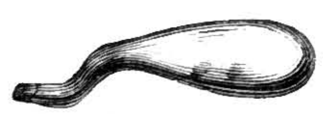

613. WORKSHOP.


607. HAMMER.

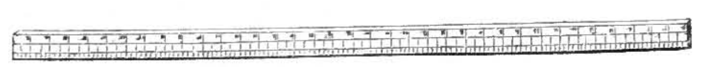

608. DOUBLE CREASE.


609. SINGLE CREASE.


610. NAIL CLAW.

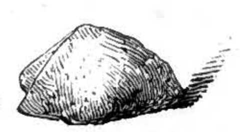

612. HAND IRON.

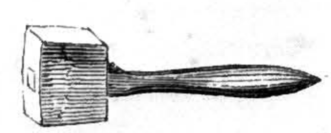

614. FILE.

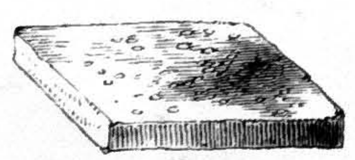

615. RULE.

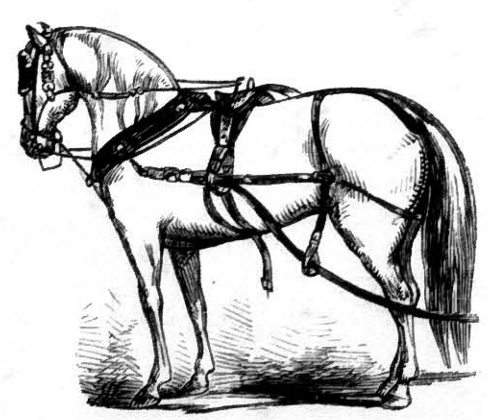

616. NEEDLE AND THREAD.


617. VARNISH POT.


618. SPONGE.


619. MALLET.


620. LEAD PIECE.


621. HARNESS.


622. PACKING AWL.


623. SEAT AWL.

XXX.—THE SADDLER AND HARNESS MAKER.

It seems always to have been the custom to place some kind of cover on the horse's back before riding him. The first kind of covering was probably the skin of a wild beast slain in the chase; and as a nation advanced in luxury, costly coverings of cloth or of leather would be introduced. Even at the present day, Eastern nations are accustomed to decorate their saddles with pearls and precious stones. The word saddle appears to be derived from the Latin verb *sedeo*, to sit, and its use is to enable the rider to sit easily. Saddles do not seem to have been introduced into England previous to the reign of Henry VII, and we do not read of the woman's saddle or *side saddle*, as it is called, previous to the reign of Richard II.

The saddle consists of a wooden frame called a *saddle tree*, which is furnished by a man called the *tree-maker;* and as the fitting of the saddle depends in great measure on the form of the tree, it is not uncommon to measure the horse's back for it, just as a man is measured for a pair of shoes. On this frame is laid a quantity of horsehair, wool, or other packing material, which is covered over with leather, neatly nailed to the wood. In order to keep the saddle steady on the horse's back a *crupper* is sometimes used, passing under the animal's tail, and *girths* to prevent it from turning round. The rider's legs are supported by a pair of stirrups, one of which is used to assist the rider in mounting; while to prevent the saddle from galling the horse's back, a saddle cloth is sometimes added. The tools used by the saddler are cutting knives, hammers, pincers, &c., represented in the figures. The *saddler's ironmonger* supplies him with stirrup irons, various kinds of buckles, bits for bridles, and other steel or brass furniture necessary for the harness, while the *horse's milliner* makes roses for bridles, and other articles used in ornamented caparisons. The saddler prepares the various kinds of bridle for coach and chaise harness. The embroiderer and the lace-maker supply him with various ornamental articles.

It is said that the best saddles and harness are made in Great Britain. There are various kinds of saddle, such as the *hunting saddle*, the panels of which must be well beaten and brushed to save the horse from a sore back, and a short saddle must not be allowed,—that is, it must not be under sixteen inches from pommel to cantle. The *running saddle* is small with round skirts; the *Burford Saddle* has the seat and the skirts plain; the *pad saddle* has burs before the seat, and sometimes bolsters under the thighs. In the *French pad saddle* the burs come wholly round the seat. In the *portmanteau saddle* there is a cantle behind the seat to keep the portmanteau from the rider. The *war saddle* has a cantle and bolster behind and before, also a fair bolster. The *pack saddle* is a saddle arranged for carrying loads.

XXXI.—THE FARRIER.

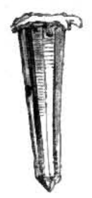
It is the business of the farrier to shoe horses, and his name is derived from the Latin word *ferrum*, iron, which is the material of which the shoes are made: indeed, the old writers call him *ferrier*, and *ferrer*.

The necessity for protecting the feet of the horse by means of iron shoes arose in great measure from our system of roadmaking; the stony, flinty surface being very different from the wide sandy or grassy plains which the horse in his wild state is accustomed to. We read in ancient history that before the use of metal shoes, the hoofs of horses were often worn away during long and fatiguing journeys, so that the animal became useless. Various materials have been used as horse-shoes, such as leather, plaited hemp, and even straw. These were used in the sense in which we employ the term *shoe*, or rather *sock*, for they were drawn on to the foot instead of being fastened beneath it. The present practice of shoeing horses appears to have been introduced into England about the time of the Conquest.

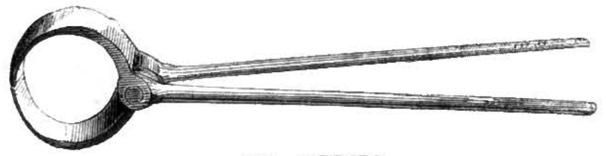
The necessity for horse-shoes will appear from a moment's consideration of the structure of the hoof. This consists of a hard *crust* or rim, nearly surrounding the lower part of the foot: it is formed of horn, or horny fibres, and has no sensation. The crust is attached to the lowest bone of the leg, called the *coffin bone*. Within the cavity of the hoof is a wedge-shaped substance called the *frog:* this was formerly supposed to be a sheath for the protection of the inner and softer parts of the foot, and farriers, impressed with this idea, made the shoe thick enough to raise the frog from the ground. It was suggested, however, that the function of the frog is to share in the pressure on the foot, and by its elasticity to relieve or distribute the pressure on the hoof. Experience seems to have confirmed this view, so that, instead of making the heel of the shoe so high as to raise the frog from the ground, it is now usually formed so as to allow it to press on the ground.

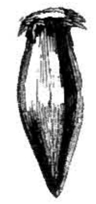
Some horses secrete the horny material of the foot more abundantly than others, so that about every three weeks the *drawing knife* (fig. 649) of the blacksmith has to be applied, and the shoes replaced. It was formerly the custom to pare down the hoof by means of an instrument called a *butteris;* a custom which is happily almost obsolete. Moisture is beneficial to the health of the horse's foot, so that, when circumstances require it, it should be stopped with damp tow. In hot stables among dry litter, the hoofs become dry, hard, and brittle, so that in shoeing large pieces will split off, even though very fine and thin nails be used. A remedy for this is exercise in the open air (which cures so many evils among ourselves), and turning the horse out to graze.

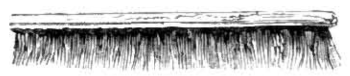
The best wrought iron should be used for horse-shoes: sometimes small pieces of steel are attached to the part most liable to wear. The width and thickness of the shoe vary with the strength and age of the horse, the purpose for which he is employed, whether for draught, riding, &c. The weight of the shoe varies from 12 to 20 ounces for carriage and saddle horses, while for the heaviest draught horse it may be some pounds. The shoe is forged from a rod of bar-iron of about an inch and a quarter in width, and three-quarters of an inch in thickness. The farrier's shed (fig. 645) resembles in many respects the blacksmith's shop. The forge is a kind of furnace for heating the rods, and is enclosed with a hovel which leads into the chimney; while at the back, against the



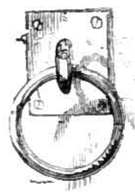
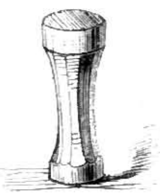
625. PUNCH. 626. SHOE.

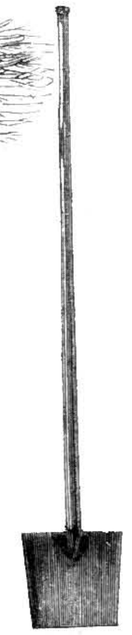

624. NIPPERS.


627. STAMP.

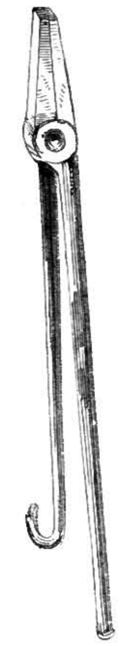

628. BRUSH.

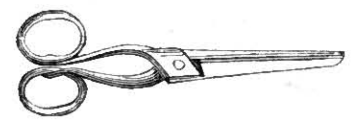

629. NAIL.

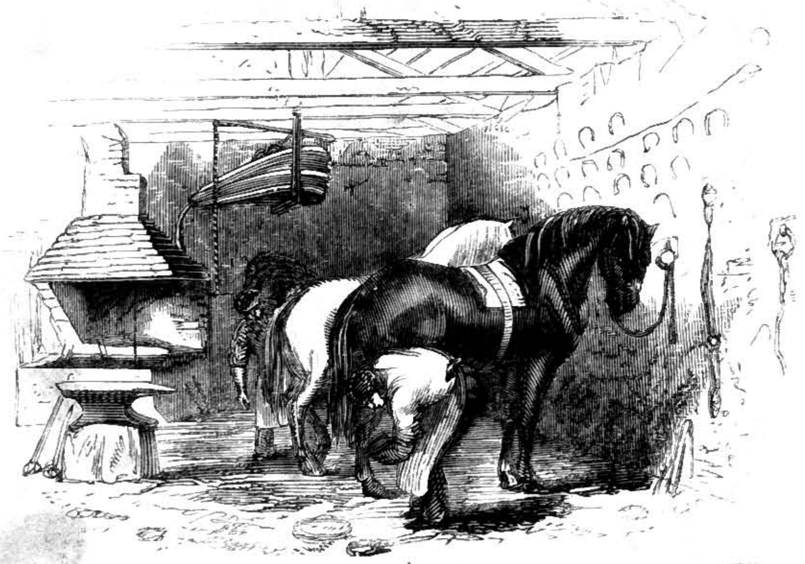





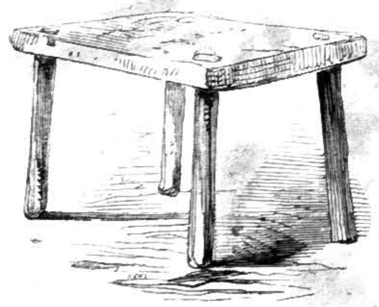

630. STAPLE. 631. POINTING STAKE. 632. FULTER. 633. DAMPER. 634. SLICE. 635. POKER. 636. LADLE. 637. SPATULA. 638. TONGS.


639. SCISSORS.

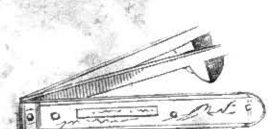

640. BUFFER.

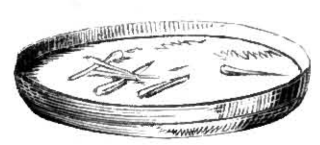

645. FARRIER'S SHED.

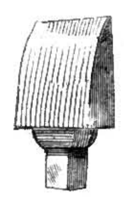

642. PRETCHEL.

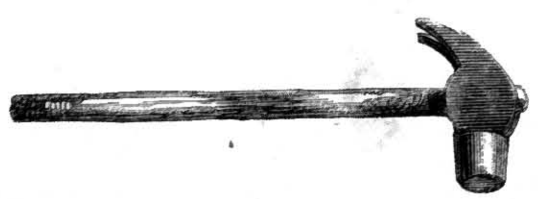

643. STOOL.

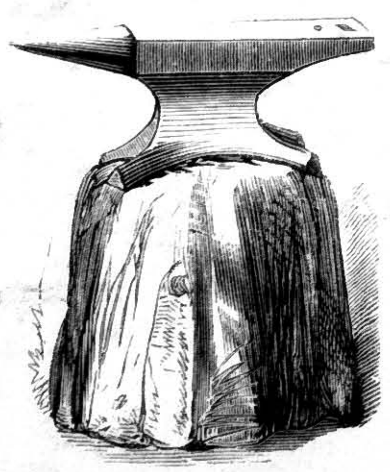

641. REACHING IRON.

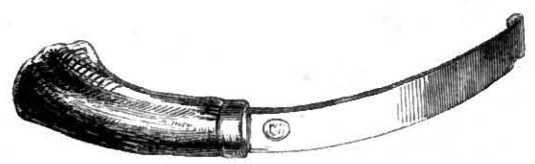

644. FLEAM.


646. NAIL BAG.

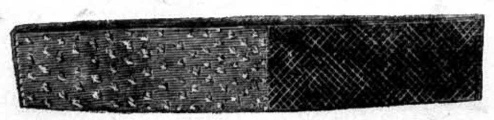

647. SWAGE.


648. SHOEING HAMMER.


651. ANVIL.


649. DRAWING KNIFE.


650. TURNING HAMMER.


652. RASP.

fire-place, is a thick iron plate, for receiving the nose of the bellows. The bellows is above and behind the forge, and is worked by means of a rocker, with a string or chain fastened to it, which the workman pulls: one board of the bellows is fixed, so that by drawing down the handle of the rocker the upper moveable board rises, but being loaded with a weight, sinks again, and thus produces a blast of air in the pipe. In front of the forge is a trough of water, which is used for wetting the coals, cooling the *tongs* (fig. 638), with which the hot iron is held, and also for hardening the iron by suddenly quenching it. The *anvil* (fig. 651) is sometimes made of cast iron, but should properly be of wrought, and faced with steel. The common smith's anvil consists of the *core* or *body*, the four corners for enlarging the base, the projecting end, containing a square hole for the reception of a *set*, or *chisel*, or *swage* (fig. 647), used in cutting pieces of iron, and the *beak*, or conical end, used for turning pieces of iron into a curved or circular form. The anvil is usually placed on a loose wooden block, such as the root end of an oak-tree.

In forging a horse-shoe some parts of the work require a hammer of peculiar form, the head being almost spherical: it has two flat faces; one rounded face for the inside of a shoe, and one very stunted *pane* at right angles to the handle, used for drawing down the *clip* in front of the horse-shoe. What is called the *turning-hammer* is shown fig. 650. Eight or nine holes are punched in the shoe to receive the nails by which it is fastened to the foot, and there is also a groove forged in the shoe to prevent the heads of the nails from projecting.

A horse-shoe does not last more than a month, and when the work is very rough, only a few days. The shoe cannot be too light, provided it does not bend. Some prefer the toe to be cut short, and nearly square, with the angles just rounded off, and it is said that if a nail be driven in at the toe the horse is liable to stumble.

A *farrier's pouch* consists of a leathern bag, containing *drivers*, *nippers*, *shoes*, *nails*, &c., for new shoeing. The *shoeing hammer* is shown fig. 648, the *horse-shoe nail* fig. 629, and the *rasp* with which the work is smoothed off, fig. 652. The other tools scarcely require notice. The *fulter* (fig. 632) is a chisel held by a hazel rod, to prevent concussion, and is used for cutting off the shoe after it has been forged at the end of the rod. The farrier formerly practised the elements of veterinary surgery, and even now undertakes to bleed a horse, which he does by means of the *fleam* or *lancet* (fig. 644).

XXXII.—THE PRINTER.

The Germans have done well to erect a statue in honour of the man who first discovered the art of printing with moveable types of metal; for there is assuredly no invention which has conferred greater benefits on mankind, or more honour on the author of it, than this. Before the introduction of this art, in the middle of the fifteenth century, books could only be produced by the costly method of copying by hand with pen and ink upon parchment. A book had then the value of a house, or a small estate, and persons have been known to pledge their houses and lands for the safe return of a book confided to their care. Before the invention of printing, the Bible was not even in the hands of the rich, and it is doubtful whether they could have read it, had they had the opportunity. Even in the religious houses, where one would expect to find men deeply versed in the Sacred Scriptures, it was rare to find a complete set of them. One monastery might possess a book of the Old Testament, another one of the Gospels, a third one of the Epistles, and so on; so that a man might travel over wide districts without having an opportunity of reading more than fragments of the Bible. The richer monasteries had attached to them a writing-room, called the *scriptorium*, and it was held to be a pious work for a man to devote himself to copying the Scriptures and *illuminating* them,—that is, adorning the vellum page with drawings and devices, and often with coloured pigments and gold. Many of these illuminated books are still to be seen in large libraries, and they fetch very high prices.

Books then being so costly, we do not wonder that an ingenious man should have endeavoured to produce them with greater facility: the wonder is that we do not read of many attempts previous to the time of Gutenberg. His first trials were made in the city of Strasburg, and his first idea was probably suggested by the *block-books*, which had for some years been common. These consisted of small books of pictures, each page containing the figure of a saint, or of a group of persons, with inscriptions under them, or running round the page. In order to produce one such page, a block of wood was taken, and a drawing having been made upon it, an engraver cut away all the white portions of the wood, so as to leave the lines of the drawing or of the writing in relief. This is precisely the process by which wood-engravings are produced at the present day, such, for example, as illustrate the book now in the reader's hands. The page so engraved, having been covered with ink, a piece of damp paper was placed upon it, and in this way it was passed through the press. A number of such pages having been thus produced, they were arranged in twos, pasted back to back, and, when bound or stitched, formed a block-book. Many such books are to be found in public and other libraries, and they are eagerly sought for by bibliographers.

Now Gutenberg's first idea was a happy one. It occurred to him that if the letters thus drawn and engraved on wood were separated by cutting up the block, they could be arranged so as to form a page of reading, and, when a number of impressions had been taken, could be re-distributed, and composed into another and a different page; for it is obvious that any particular page of a block-book could only be used for that page, and when a different page was wanted, the whole process of drawing and engraving had to be gone over again. Gutenberg, however, found that his wooden types soon split and warped, and became useless; when it occurred to him to cut or chase the separate letters in metal, but this was found to be as costly as the labour of the scribe. He therefore attempted to cast his letters separately, in plaster moulds, but the results were so rough and uneven that he abandoned the idea in despair. Having spent all his own money, and a good deal of other people's, he applied for assistance to a rich goldsmith of Mayence, named Fust or Faust, who, it must be admitted, took advantage of the necessities of the poor inventor to drive a hard bargain.

GREAT PRIMER.—This is sometimes called *Bible text*, as it is seldom used in printing any other books than the large folio Bibles. The French call it *Great Roman.*

ENGLISH.—This is used for printing Bibles, large books, and the body of hand-bills. The French and Dutch call it *St. Augustine;* it is supposed, therefore, that this sized type was first used by those nations in printing the works of that writer.

PICA.—This is the standard by which all the others are measured. It is more generally used than any other sort, especially in printing works of a high character. The French and Germans call it *Cicero*, it having been originally used by them in printing the Roman orator's epistles.

SMALL PICA.—This is the favourite type for novels. It is called *brevier* by the Germans, and *philosophie* by the French.

LONG PRIMER.—This sort is generally used for printing small books, or large books with close pages. The French call it *little Roman*, and the Germans *corpus*, it having been used by them, in the first instance, for printing the *Corpus Juris.*

BOURGEOIS.—This type is very much used, and generally forms the largest type employed in printing newspapers. Bourgeois is a French word, signifying a *citizen*, and the name is applied to it in England as expressing the common use of the type. The French themselves call it *gaillarde.*

BREVIER.—This is employed in printing small cheap books, and for notes to larger type. It is supposed to have derived its name from the practice of using it to print breviaries, or Roman Catholic church books. The French call it *little text*, and the Germans *maiden letter.*

MINION.—This type is very largely used in printing newspapers, as well as in small prayer-books and bibles, and pocket editions of other works. The Germans call it *colonel*, and the French *mignonne*, or favourite.

EMERALD.—This is a small kind of Minion, used chiefly in Newspapers and Bibles, and only lately introduced.

NONPAREIL.—This type is so called because it is far more beautiful than any other sort. It possesses all the beauty, without losing the distinctness of the larger sorts.

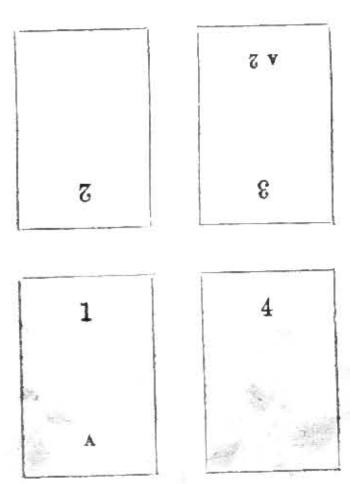
RUBY. This is, like Emerald, an interpolation in the original order of types. It was, at first, a Nonpareil body with a smaller face. The French have no type which corresponds with it.

PEARL.—This is only used for miniature books and notes, and is legible only to persons possessing strong sight.

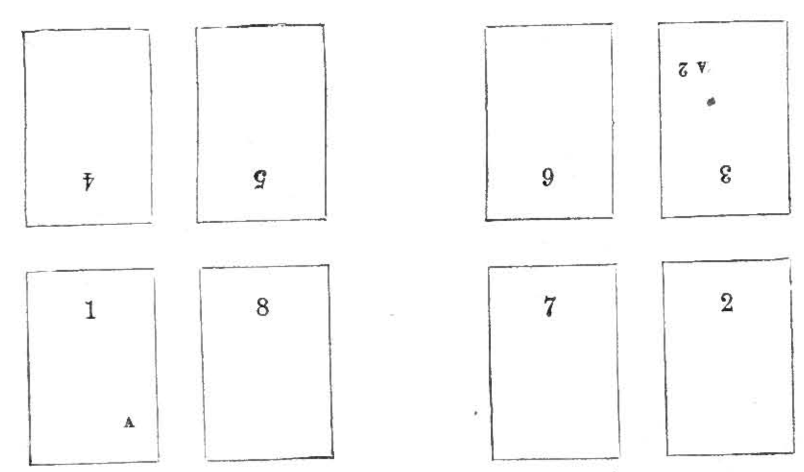
DIAMOND. This is the smallest sort of type in general use, and was first cut by the Dutch. A book printed in this type is indeed a curiosity, like the Lord's Prayer written on the size of a sixpence. The letters are so small, that 2,800 of them are contained in a pound weight. We may add, however, that a type still smaller was cast by M. Didot, a French printer.

BRILLIANT. This is the smallest type cast in this country. It is chiefly used for marginal notes and contents of Chapters to the Diamond Bibles. Strong or rather near sighted eyes are required to read it, and microscopic eyes to arrange the letters for printing. It is cast only by Miller and Richard of Edinburgh and London.

A SHEET OF FOLIO, CONTAINING FOUR PAGES, TWO ON EACH SIDE.

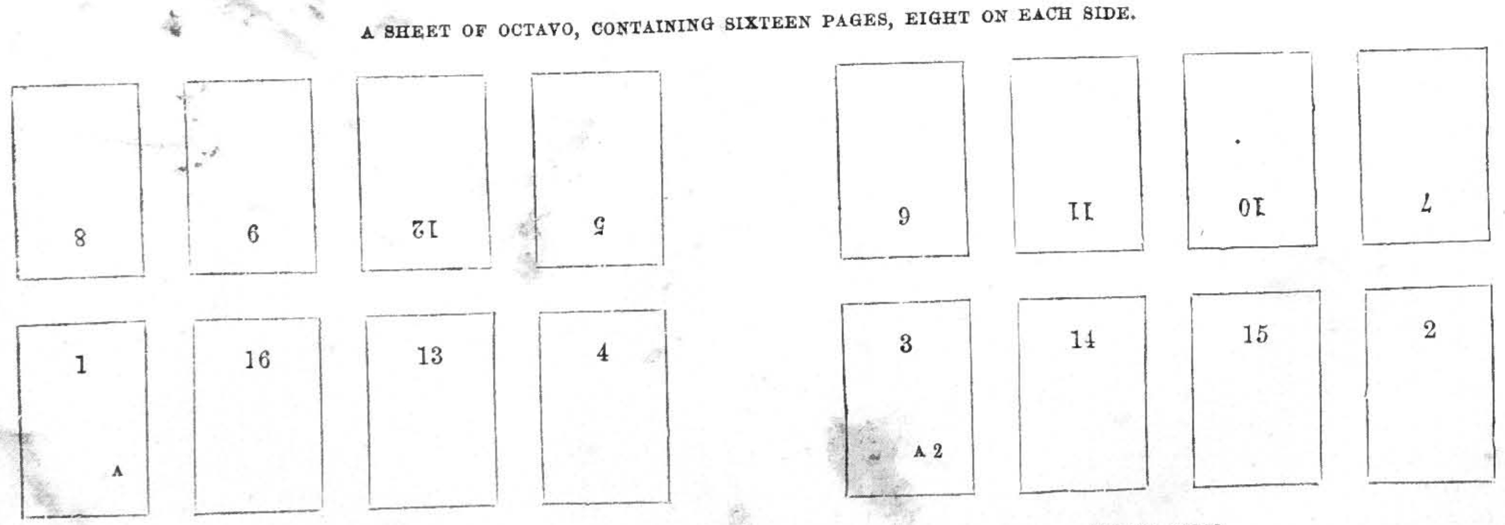


A SHEET OF QUARTO, CONTAINING EIGHT PAGES, FOUR ON EACH SIDE.



OUTER FORM. INNER FORM.

A SHEET OF OCTAVO, CONTAINING SIXTEEN PAGES, EIGHT ON EACH SIDE.



OUTER FORM. INNER FORM.

Wealthy men are often not more liberal to poor inventors of the present day. Fust does not appear to have assisted the invention, except by appropriating it, but he called in one Peter Schœffer, a scribe, and promised him, it is said, the hand of his daughter if he could bring the invention to bear. The three partners deliberated long and anxiously on the subject, and made many experiments, when at length it seems to have occurred to Schœffer to form for each letter a punch of some metal, such as could be cut by hand while soft, and, when finished, be hardened. By means of this punch a sunken impression could be made in copper, or some such metal, so as to form a *matrix* which would reproduce the letter any number of times, by the ordinary process of casting. Such is, in fact, the modern practice of type-founding. The plan turned out to be perfectly successful. A fount of type was produced in this way, not of the Roman letters which we are accustomed to in books, but letters resembling the writing-hand of the period. For it must be remarked, that although these three men—Gutenberg, Fust, and Schœffer—were instruments in the hands of Providence for working out a purpose for the good of mankind, they were not aware that such was the case, but had their own interests keenly in view. They kept their processes strictly secret, and hence, in order not to excite too much inquiry, they made their printed books to imitate as far as possible the written books of the period. Before, however, their first book was printed, the partners had disagreed, and Gutenberg left the concern, himself in debt, and all his printing materials deeply mortgaged to Fust. Within eighteen months of this event—namely, in August 1457—Fust and Schœffer produced the Psalter, printed in large type; and in 1460 they published the celebrated Latin Bible. No sooner was this work accomplished than an event occurred which, humanly speaking, would seem to have been disastrous to the young art; namely, the siege of Mayence in 1462, the breaking up of its trade, and the dispersion of its artisans. Among the workmen thus dispersed were the journeymen of Fust and Schœffer, and wherever they went they spoke of the marvellous success of the new art, and competent men took it up, so that within six years of the publication of the Psalter, there were printing-presses in several considerable towns, and within fifteen years this great privilege had extended to every considerable town in Europe.

The plan and limits of this work do not allow us to enlarge upon the history of printing; but we have thought it right to give the above details on account of their singularly instructive and suggestive nature. Men are too apt to forget that inventions which have a first-rate importance on the destinies of mankind are not of sudden growth, but are prepared by long antecedents, by which the world is made ripe for the invention, and is able to appreciate it. Such an invention might have been useless or even mischievous at an earlier period; but coming just at the right time, as in the case of printing, when men's minds had begun to awake from the intellectual slumbers of the dark ages, they could appreciate the beauties of Roman and Greek literature, and above all were preparing in various ways for a purer faith, which was consummated by the Reformation: no time could have been so fitting for the invention as this, which was to place a Bible in every man's hands, and enable him to give a reason for the faith which was in him. Considering all these things, shall we not say of the Printer as the Prophet of old said, when speaking of the labours of the ploughman and the sower, "For his God doth instruct him to discretion, and doth teach him?" (Isaiah xxviii. 26.)

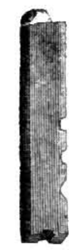
The first step in the art of printing is taken by the type-founder. His art is one of great complexity, not only on account of the large number of sizes of type in common use, but also the large variety of *sorts* or characters belonging to each size. There are two kinds of founts in use, the one for *book-printing*, and the other for *job-printing*, the latter including such work as hand-bills and posters. Book-types include eleven or twelve regular bodies, from *Great Primer*, which is the largest, to *Diamond*, which is the smallest type used for printing books.

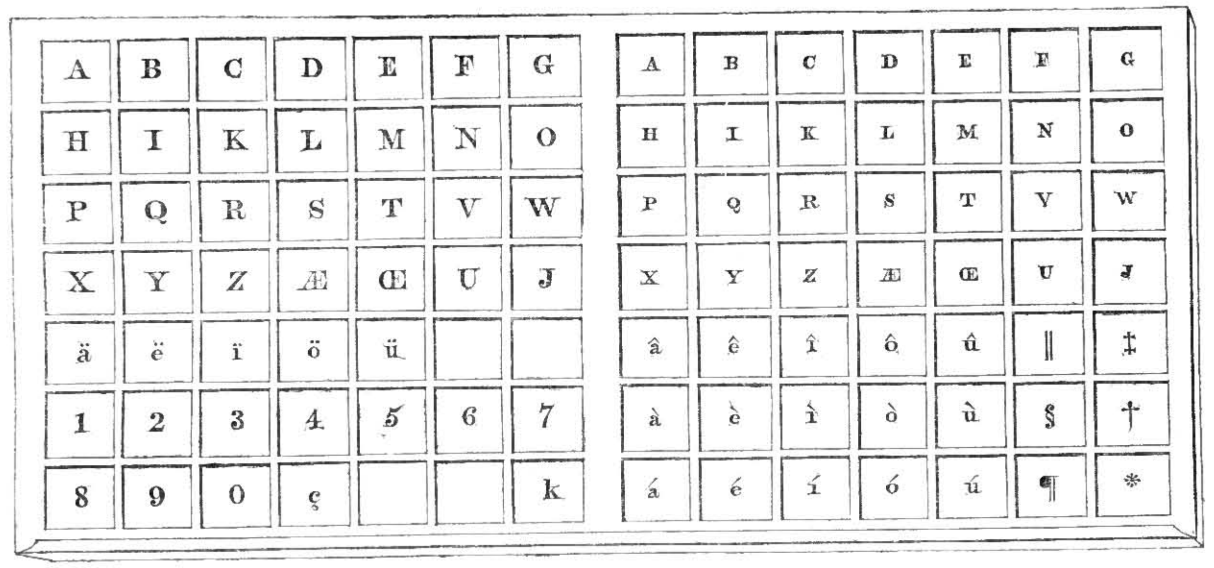
A set of types was anciently called a *fund;* it is now called a *fount.* The different letters bear a fixed proportion to each other. Thus a fount containing 8,500 a's will have 1,600 of b; 3,000 of c; 4,400 of d; 12,000 of e; 2,500 of f; 1,700 of g; 6,400 of h; 8,000 of i; 400 of j; 800 of k; 4,000 of l; 3,000 of m; 8,000 of n; 8,000 of o; 1,700 of p; 300 of q; 6,200 of r; 8,000 of s; 9,000 of t; 3,400 of u; 1,200 of v; 2,000 of w; 400 of x; 2,000 of y; 200 of z.

The numbers vary in this way, because some letters are more used than others. It has been found, for instance, that 200 *z*'s are sufficient where 12,000 e's are required. The capital letters of a fount are also proportioned to each other similarly to the other letters. To these must be added the spaces, which are small pieces of metal used to separate the words: they are shorter than the letters, so that in inking the type the ink does not touch them, and, as they make no mark on the paper, they create a blank space between the words. The spaces are of four sorts,—*hair, thin, middle,* and *thick* spaces. Besides these there are *quadrats*, or larger spaces, to fill out the breaks in sentences; these are *n* and *m* quadrats, and two, three, and four *m* quadrats. The shank or body of the *m* quadrat is a perfect square, and is, therefore, used in measuring, just as an inch is in a foot.

The different kinds of type are measured by one standard. This type is the sort called *pica.* On the preceding page (90) are specimens of the types used in printing books, together with their names and some particulars respecting them. Besides these, there are others which are used for placards: for instance, *paragon; double-pica; two-line pica; two-line English; two-line great primer;* and *canon*, which is four times as large as pica. The types larger than canon have no distinct names, but are known as *five, six, seven, twenty,* or *fifty-line pica*, according to their size; that is, they are as wide, or as printers say, as deep, as five, six, seven, &c., lines of pica. For instance, the letter (fig. 682) is "ten-line pica Egyptian," and is as deep as ten lines of pica put together. Above 12-line pica, the letters are usually cut in wood—not cast in metal.

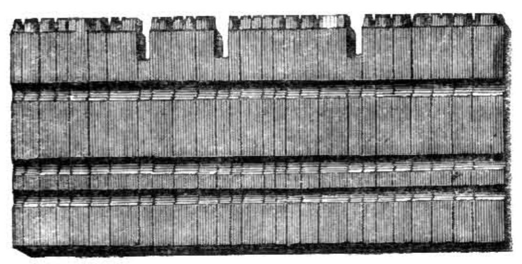
We have already given the broad outline of the art of type-founding as invented by Schœffer. Modern practice does not differ from it in principle. There is a separate mould or matrix for each separate letter of the alphabet, and no less than 320 punches, and, of course, the same number of matrices, for the different varieties of letters, capitals, and small capitals, Roman and Italic, which form a complete fount of type. Fig. 653 is the form of a letter, which represents the shape of the interior of the mould. The mould is enclosed in two flat pieces of wood, and the metal is poured into it through a small funnel-shaped top. The type-metal is a mixture of lead, antimony, and tin, the proportions of which vary slightly with different type-founders; some add a minute portion of copper. Antimony expands in passing from the fused or liquid state into the solid, so that its presence has the effect of filling up the mould and producing sharp well-defined type. The caster, after he has poured in the metal, jerks the mould upwards, by which the air is expelled, and the metal is forced into every part of it, so as to form the letters perfectly. Such letters as f and j, of small sizes, are now generally cast by the aid of a force-pump attached to the melting-pot, an improvement that saves the caster much time and trouble. The metal sets, or becomes solid, as soon as it has entered the mould. The process of casting, though apparently very primitive and clumsy, is performed with considerable expedition. A good workman will close the mould, cast the letter, open the mould, and remove the letter, in the eighth part of a minute; that is, he will cast 500 letters in an hour. The type made by hand is considered the best; but type is now made by machinery at the rate of thousands per hour. Each type as it is cast contains a piece of superfluous metal, which is broken off by a boy; the sides of every letter are then rubbed on a slab of gritty stone, for the purpose of removing knobs or globules; the letters are next set up in lines in a shallow frame, with the faces uppermost and the nicks outwards, when a man, called the *dresser*, polishes the types on each edge, and turning them with the face downwards, planes the bottom, and forms the groove which brings the types to the required height, and

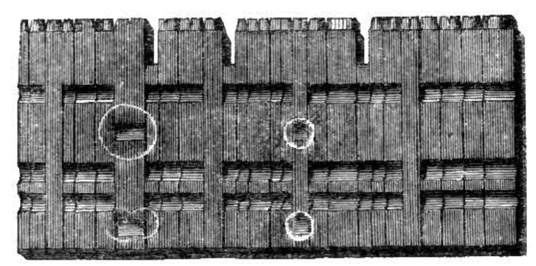

653. SINGLE LETTER.

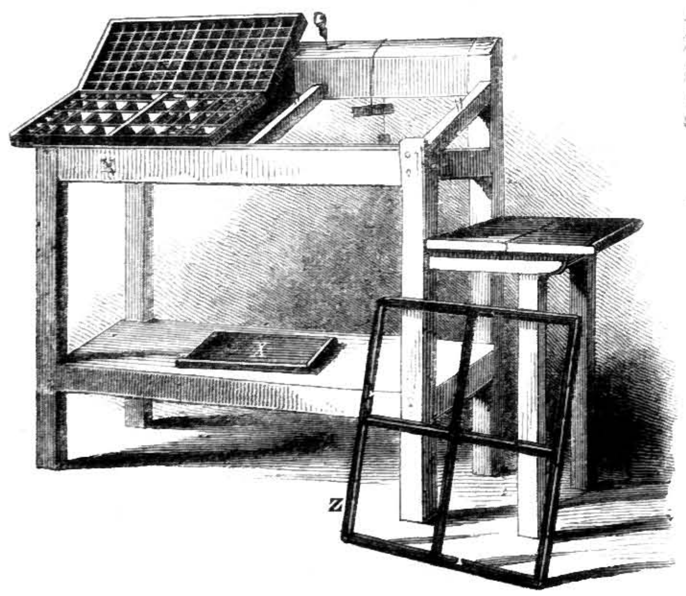


654. UPPER CASE.

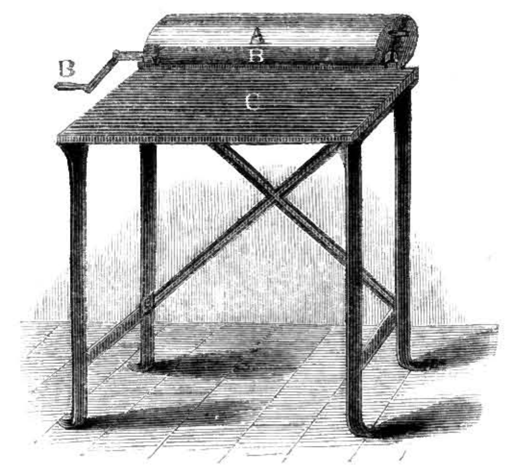

655. BODKIN.


656. LINE OF TYPE, CORRECT.

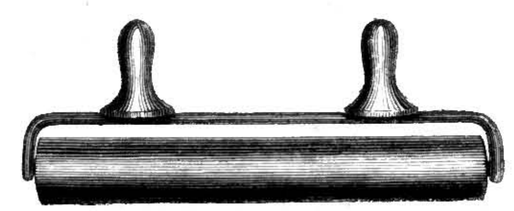

657. LINE OF TYPE WITH WRONG SORTS.

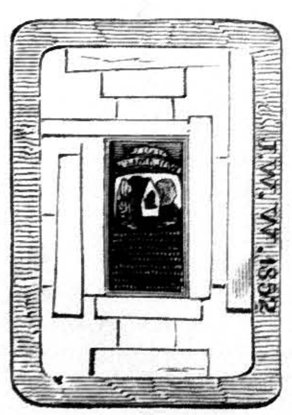

658. FRAME AND CASES.

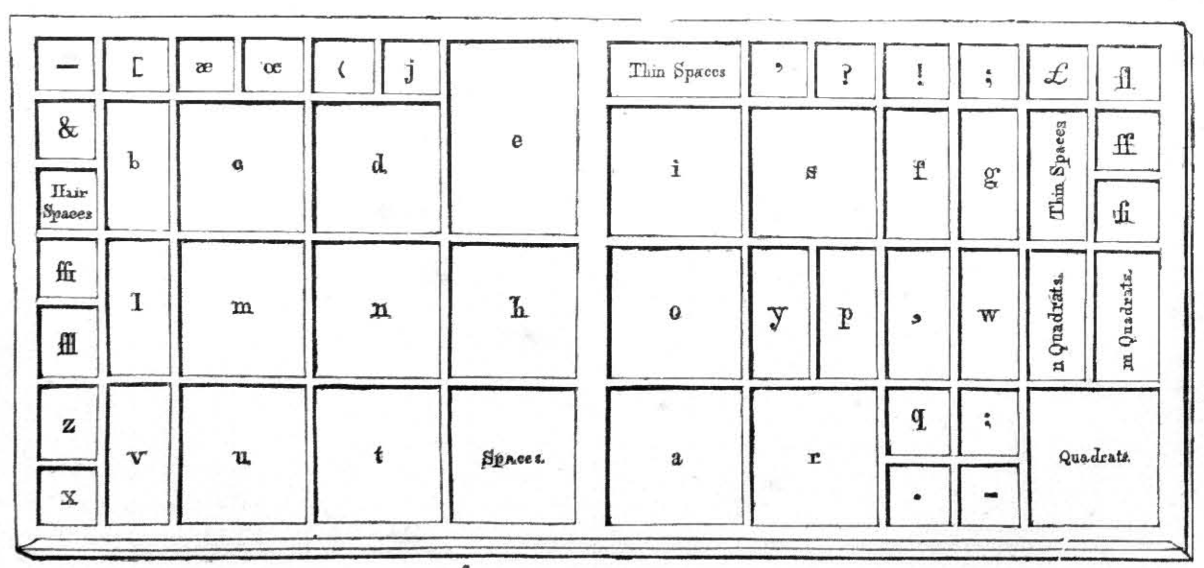

659. STATUE OF GUTENBERG.


660. INKING TABLE.


662. SIDE-STICK.

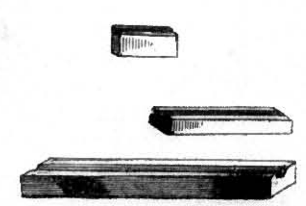

661. INKING ROLLER.


663. CHASE.



664. LOWER CASE.


665. REGLET.


666. FURNITURE.

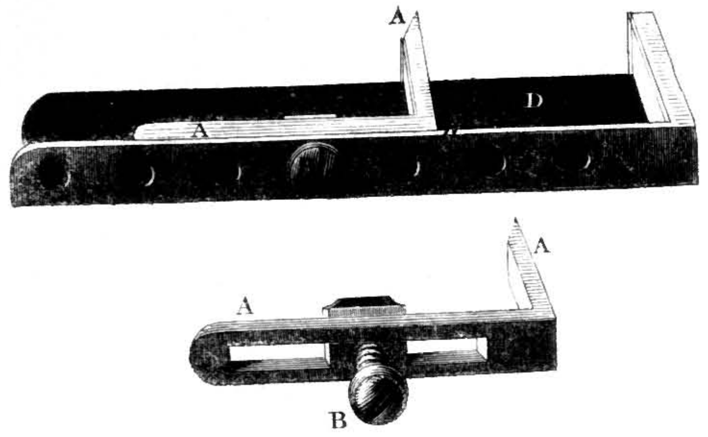
allows them to stand steadily. The letters are next carefully inspected with a lens, and the fount being *proportioned*,—that is, the proper proportion of each letter, with spaces, quadrats, &c., being counted out,—each letter, &c., is tied up in lines for the printer.

The type is arranged at the printing office in cases, of which there are two, the *upper* and the *lower* case (figs. 654, 664). The upper case is divided into equal spaces or *boxes*, the left-hand division containing capital letters, dotted letters, figures, fractions, and a few other particular sorts; the right-hand division containing small capitals, accented letters, and note references. In this case the letters and figures are arranged in their alphabetical and numerical order, from left to right. In the lower case the divisions are unequal, the largest boxes being given to those letters which are most in request. The letter e has the largest box; c, d, m, n, h, u, t, i, s, o, a, r, have each boxes twice the size of those containing b, l, v, f, g, y, p, w, and four times the size of x, z, j, q, or the crochets [ ], points and full points, double and treble letters, &c. The letter k occupies a spare box in the left-hand division of the upper case. The logotypes, ff, fl, fi, ffi, and ffl, are required on account of the kerned f, which cannot be placed close to another f, an i, or an l. The boxes of letters most in request are nearest at hand. There is a separate pair of cases for the italic letters. The cases are placed on a *frame* (fig. 658), in which the blank space is usually occupied with the pair containing the italic fount.

The person who sets up the type is called a *compositor*. He stands before the case, and placing his *copy*,—that is, the author's manuscript,—on a part of the upper case which is but little used, begins to pick up the letters required for the first words of the MS. In his left hand he holds a *composing stick* (fig. 667), in which the letters are arranged into words and lines: it is usually of iron, from seven to ten inches long. The ledge *AA* is a moveable slide which can be adjusted by means of the screw *B* into any one of the holes, so as to make the space *D* wider or narrower, according to the width of the page which is to be printed. The compositor next selects a piece of brass rule, called a *setting* or *composing rule*, of the exact length of the line, and with a small ear or beak projecting at one end. This allows the letters to slip into their places without any obstruction from the screw-holes of the stick or the nicks in the type. The compositor then with the composing stick in his left hand, the fore-finger being bent under it, while the thumb is brought over the slider into the space *D*, first places the setting rule in the stick, and looking at his copy so as to carry a line or two in his memory, he takes a capital letter from the upper case and places it in the right angle of the composing stick; he selects the remaining letters of the first word from the lower case, and at the end of the word inserts a space. The compositor must make the words and spaces exactly fill the line by using thicker or thinner spaces as occasion requires. If at the end of a line the word cannot be divided, he drives it into the second line by wide spacing, or includes it in the first by narrow spacing. When he has completed the first line, he glances his eye over it to see that it is correct, and runs his left thumb along the front of the letters to feel if they are of the same fount. In this he is assisted by the nicks cut in the body of the type; and as each fount has its own system of nicks or notches, he can tell by feeling whether any of the letters are turned the wrong way, or are of the wrong fount, for in either case the lines of the grooves would be interrupted. Suppose, for example, the letter is what is called a three-nick letter, the appearance of a line will be that shown in fig. 656. But if either or both of the mistakes above referred to occur, the line will present some such appearance as in fig. 657. Having arrived at the end of the first line, the compositor takes out the setting rule and puts it in front of the line, which he forces back, and proceeds to compose the second line. In this way the setting rule serves as the basis for each new line. If the matter is to be *leaded*,—that is, if the lines are to be farther apart than the type will allow,—a flat ribbon of metal called a *lead*, of the exact width of the page, but from ¼th to ⅛th the width of the type, and of the same height as the spaces, is inserted after each line is completed and before the rule is removed. Composing is not slow work, as might be supposed, for a good compositor will set 12,000 pica letters in a day. The composing stick generally holds about ten lines of pica, and as soon as it is full, the compositor lifts them out into a *galley*, shown at *X*, fig. 658: it is simply a thin piece of board with a ledge at one side, and at one end. When enough matter has been composed to make a sheet, the compositor proceeds to *impose* a *forme*. *Imposing* is the arranging of the pages in such a manner that when the sheet of paper on which they are printed is folded, they shall follow, and read on in regular order. For this purpose the type is arranged in pages of equal length, with the same number of lines in each page, and being tied round with twine to prevent the letters from falling out, they are placed on the *imposing stone*. This is a slab of marble or of iron let into a frame. A sheet of folio which contains four pages would be laid, two pages on each side, as shown in the figure at page 90.

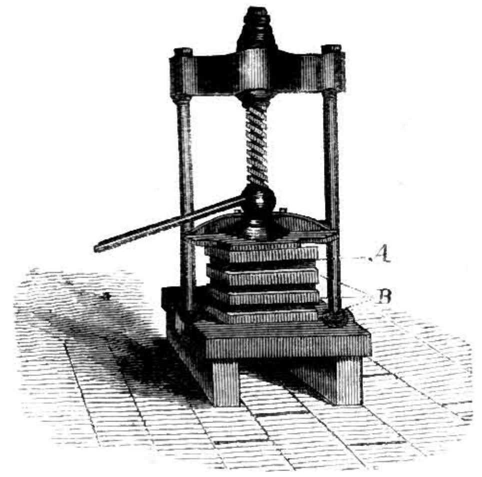
In arranging the pages, a line of quadrats is added at the bottom of each page, and at the top the *folio* of the page and the *running head*, which gives the title of the book, or of the chapter, or, still better, of the page. At the bottom of the first page the compositor places the *signature* or letter of the alphabet which serves as a guide in *gathering*, *folding*, and *binding* the sheets. The pages being properly placed, he takes an iron frame, called a *chase* (a *quarto chase*, or one for four pages, is shown at *Z*, fig. 658), which is divided by cross-bars into compartments, places it down among the pages, and arranges between them a number of pieces of wood or metal called *furniture* (fig. 666). Within the chase, next to the pages, he places other pieces called *side and foot-sticks*, which are wider at one end than at the other, and between these and the chase he drives in small wedges or *quoins*. With a mallet and a *shooting-stick* (fig. 672), he drives the quoins in, and these acting with the force of the wedge, lock up the separate pieces of type so securely, that the chase may be lifted off the stone, without any danger of the letters falling out. The chase of type is called a *forme*, and there are two formes, the outer and the inner forme, for every sheet. (See the figures at page 92.)

When the formes are removed from the stone, they are taken to a hand press, and a *proof* or impression of the sheet is *pulled*. This proof is placed in the hands of the first *reader* or *corrector of the press*, who folds the sheet, examines the signatures, the folios, and the running heads; sees that the pages have been properly imposed, the chapters correctly numbered, the underlined words set up in italics, and the work done properly. A *reading boy* then reads the copy aloud in a rapid manner, and the reader corrects the mistakes of the compositor by drawing his pen through the letter or letters, and writing the correction in the margin. Then writing on the author's copy in the proper place the commencement, signature and folio of the succeeding sheet, he returns the sheet to the compositor, who proceeds to make the required corrections, for which purpose the forme is placed on the stone, the type loosed or unlocked, and then, taking out by means of a *bodkin* (fig. 655) the wrong letter or letters, he inserts the correct ones. Should the compositor have omitted a sentence, he may have to do a great deal of his work over again, for he may have to *overrun* a large number of lines or even of pages, before he can get in the proper insertion. The errors being corrected, a second proof is pulled, which with the original proof goes back to the first reader, who sees that his corrections have been attended to, and, if he is satisfied, forwards a clean proof to the *second reader*, who submits it to a searching revision, and marks not only compositors' mistakes, but queries the author's meaning, when it is, as it often is, obscure. The technical corrections of the second proof having been made, a clean proof is pulled for the author; the queries are marked in, in ink, and the proof with the copy is sent to the author. Should the author be satisfied with it, he returns it marked "For Press;" but should his corrections be numerous, he may require to see another proof, in which case he marks it "For Revise," and a second proof is sent to him, when his corrections have been made. When returned for press, it

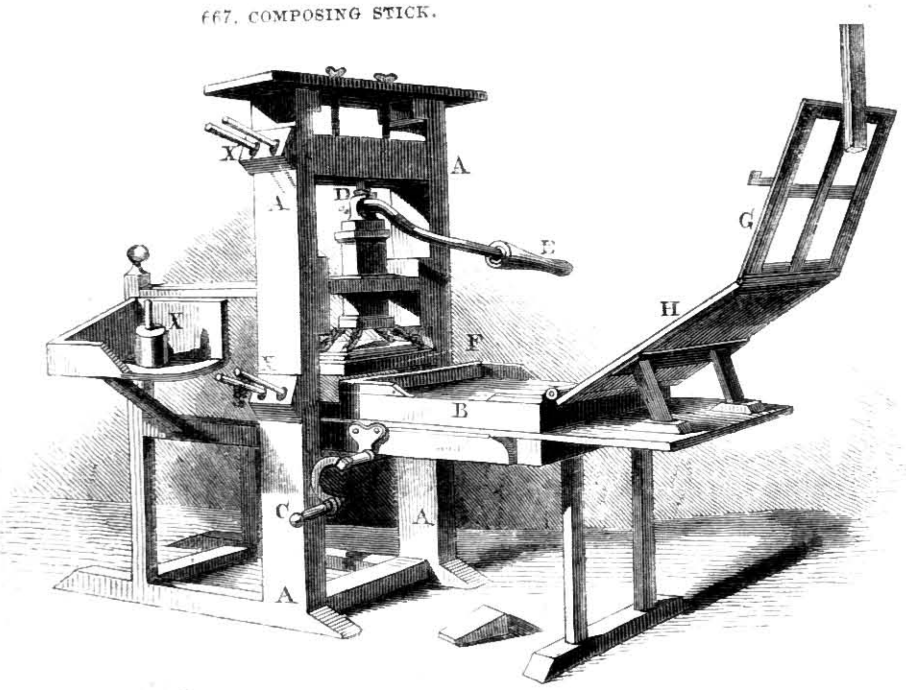


667. COMPOSING STICK.

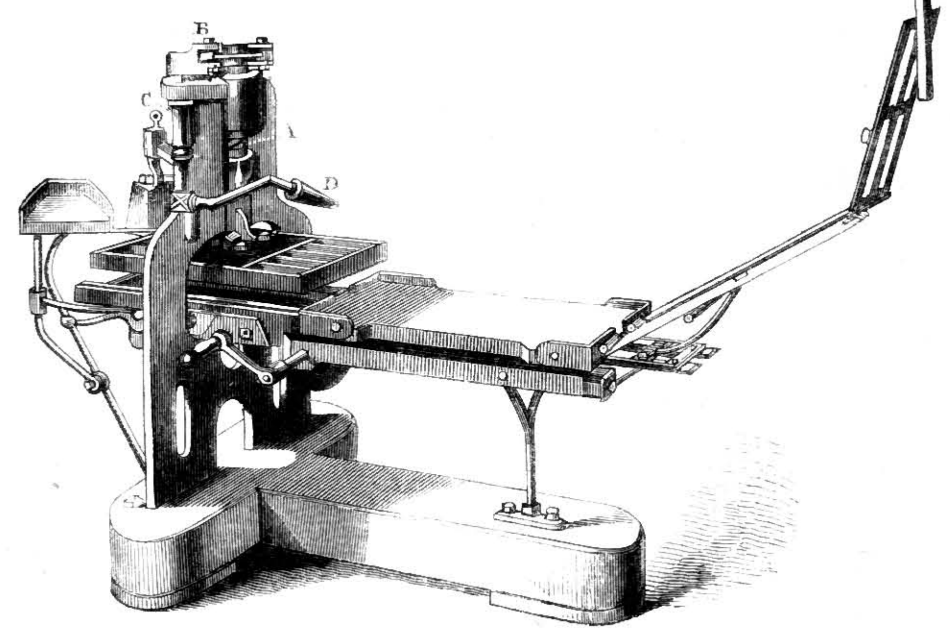
668. PRINTER'S HORSE AND BANK.



669. SCREW PRESS.



670. FIRST PRINTING PRESS.

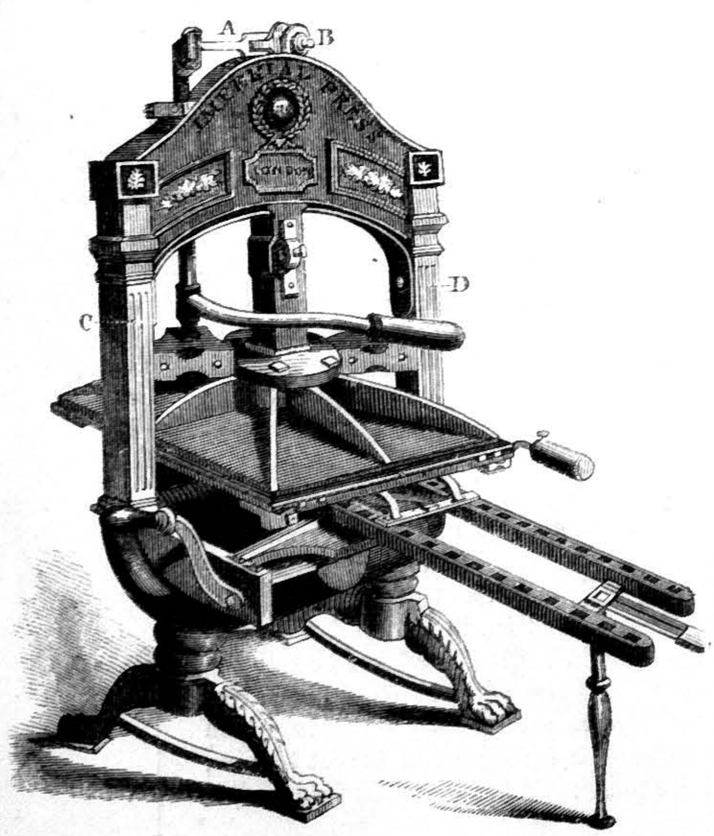


671. STANHOPE PRESS.

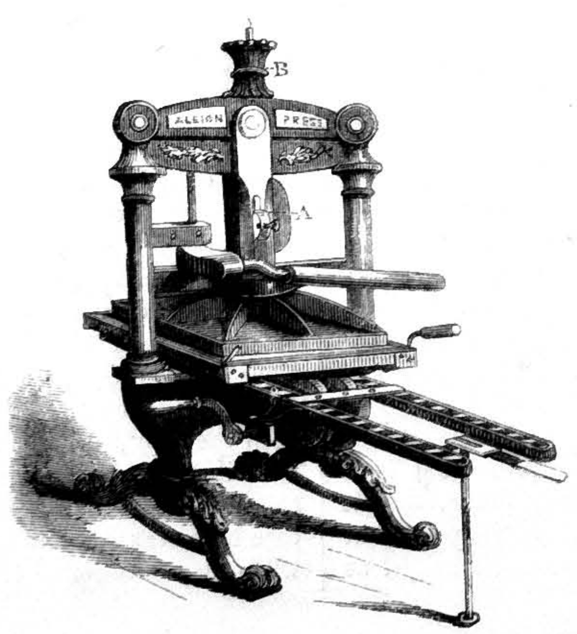
672. SHOOTING-STICK.

673. BRIER.

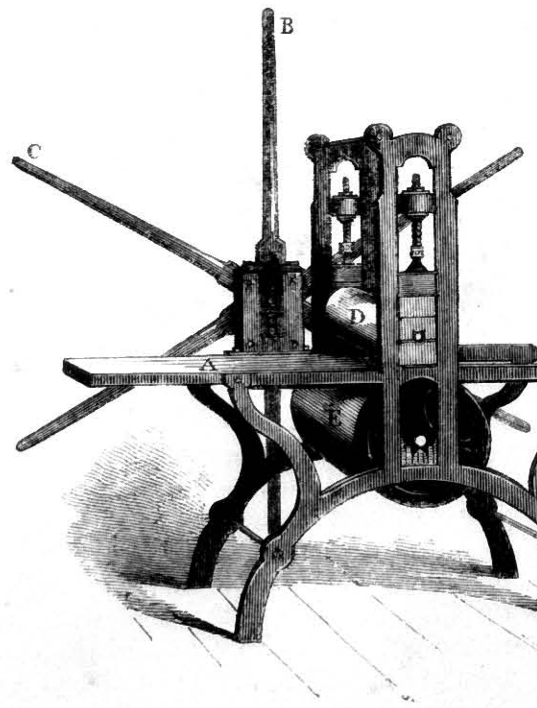
674. PLANER.



675. IMPERIAL PRESS.



676. ALBION PRESS.



677. COPPER PLATE PRESS.

is once more read for the purpose of detecting minute technical errors, correcting the spacing, &c., and it is lastly sent to the press-room to be printed off. In the meantime the compositor is setting up another sheet of the work, and goes on until his type is exhausted; but before that happens, the first sheet will probably have been printed off, and the type returned to the compositor, who *distributes* it in his case by taking up a few words at a time between his finger and thumb and spelling out the letters into their proper boxes.

An old form of printing-press is represented in fig. 670, in which *A A* is the framework; *B* the board or table on which the types are placed to be printed; *C* the handle by which the table is rolled in to receive the pressure, the table standing on runners not unlike a railway. *D* is the screw, *E* the handle, and *F* the *platen*, by which the pressure is given. *G* is the *frisket*, an iron frame covered with paper, which in the engraving has been cut into four holes for the printing of four pages of type; and *H* is the *tympan*, consisting of a fine blanket laid between two skins of parchment, which are stretched on a square iron framework. The type to be printed is laid on the table, and inked with a soft roller, made principally of boiled glue and treacle. The printer lays a sheet of paper on the tympan, and turns down the frisket upon it. The object of the frisket is to keep the paper from falling off the tympan, and to prevent any part of it, except those parts which are to be printed on, from being inked, or, in other words, to keep that part of the sheet which is to form the margin, from getting soiled. After laying on the sheet, and turning the frisket down upon it, the printer doubles the tympan and frisket together, and turns them down upon the types, and then, turning the handle, he rolls the whole *carriage*, as it is called, under the platen. The bar is then pulled, the screw is thus turned round, and, pressing down the platen, the printing of the sheet is effected. The bar is then suffered to resume its former place, the screw thereby lifts the platen, the printer rolls out the carriage, unfolds the tympan and frisket, and removes the printed sheet.

The first improvement in the printing-press was made in 1620 by one Blaeu, or Blew, a Dutchman; and his press continued in use until the beginning of the present century, when it was superseded by the *Stanhope press* (fig. 671), so called after Lord Stanhope, the inventor of it. His improvement consists in giving to the handle the power of a bent lever. The handle of the press previously used was fixed on the screw by which the pressure was given. Instead of this arrangement, Lord Stanhope succeeded in connecting the top of the screw, by a short lever and a link, to the top of a spindle placed parallel to the screw. The handle of the press is attached to the end of this spindle; and when the workman first pulls the handle towards him, owing to the position the levers then occupy, the platen descends very fast, but on reaching the surface of the type, where of course the pressure is required, the levers have changed their position in such a manner that the platen moves more slowly but with much greater power. *A* is the screw; *B* the levers connecting the top of the screw with the spindle *C*, and *D* is the handle attached to the screw, which being turned, by pulling the handle, forces down the platen. The advantage arising from this arrangement of levers is, that platens twice as large as those previously used can be worked with far less strength. The platen of the old press was only half the size of the sheet of paper on which books are usually printed, as may be seen by comparing fig. 670 with fig. 671; and in consequence it was necessary to roll half the table under the platen, pull the handle, and print half the sheet, then roll the other half of the table under the platen, and pull the handle again before the whole of the sheet was printed. Lord Stanhope's press, however, admits of platens being made sufficiently large to cover the whole of the sheet at one time, while the bent lever handle enables the pull to be effected with greater ease. Furthermore, the increased power of the Stanhope press allows of the use of iron, instead of wood, in its construction, and this increases its efficiency, as wood yields to the power of the screw, while iron does not. Lord Stanhope's improvement was afterwards applied to wooden presses, the power of which was greatly increased by it.

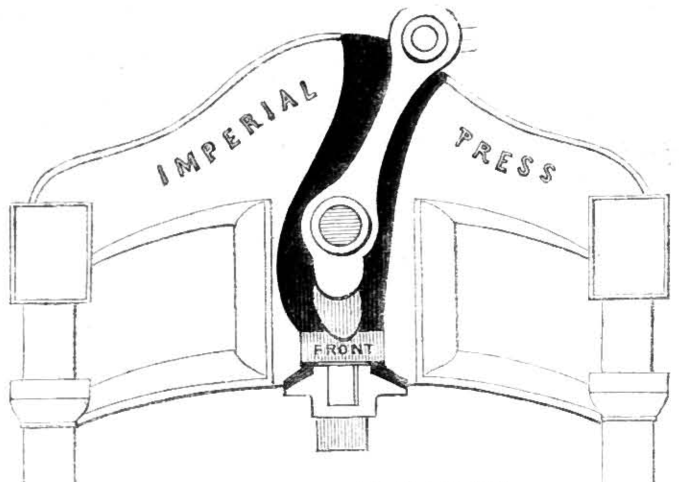
The Stanhope press suggested a still greater improvement of the press. The screw which it retained was superseded entirely by a further use of the lever. Not only is the lever now employed to increase the power of the screw, but also to do the work of the screw. There are several kinds of presses, differing in their details, but using the lever to produce the impression instead of the screw. The screw is no longer used, but the lever is applied in many different ways. In the *Albion press*, for instance (fig. 676), two wedges or levers are placed within *A*, and when the press is idle they lie together something like the letter >; by pulling the bar-handle they are straightened like the knee on rising from a sitting position, and by their greater length force down the platen upon the type, and thus produce the impression. On the return of the bar-handle to its place of rest, the platen is lifted from the face of the type by means of a spiral spring fixed in the box *B*, and the two levers fall into the shape of a > again. This press, fig. 676, and the *Imperial press*, fig. 675, are shown with the tables rolled in under the platen.

The Imperial press (fig. 675) is an improvement on the Albion. In this arrangement the bar-handle being pulled over, the levers *A* straighten the lever *B*, which fills a hole in the frame of the press, as in fig. 678. The straightening of this lever forces the platen down upon the face of the type. The platen is lifted again on the return of the bar-handle by two springs attached to the inside of the cheeks of the press, *C D*, but not shown in the engraving.

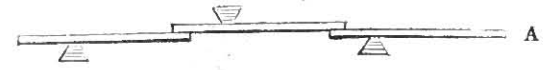
The *Columbian press* (fig. 680) is worked entirely with levers. The bar *A* being pulled, the rod *B* draws the elbow *C* inwards towards the cheek *D*, and thereby pulls down the head *E*. The head is not a fixed and immoveable part of the frame, as in other presses, but is a large lever, its fulcrum being the cheek *I*. The platen *F* is attached to the head by an iron bar *H*, and when the head is pulled down, the platen beneath this bar is forced down upon the face of the type. There is another lever *K*, attached to the head bearing the eagle above it. The head in descending pulls downward the short arm of this lever, as the head rests on a fulcrum formed by the cheek *D* at *d*, and, in consequence, the opposite end, that is, *M*, bearing the eagle, is lifted upwards; this in falling draws the bar-handle back to its place of rest, lifts the platen, and raises the head.

The principle and action of the Columbian press will not be thoroughly appreciated unless the principle and action of the compound lever are understood. This press is really nothing but a compound lever applied to printing; and, indeed, this may be said also of the Albion and Imperial presses, though they do not exhibit it so fully and clearly. It is known that an ounce weight placed at one end of a lever may be made to balance a pound placed at the other end of the lever, simply by lengthening the distance of the small weight, and shortening the distance of the large weight, from the *fulcrum* or point on which the lever rests. But the power of the lever may be enormously increased by using a number of levers in connexion with each other. For instance, let it be supposed that the three levers (fig. 679) are of the same length, the long arms of each 18 inches, and the short arms 1 inch. A pound weight placed at *A* would press the short arm against the long arm of the second lever with a force of 18 lbs.; this force of 18 lbs. acting on the long arm of the second lever would press down its short arm with a force of 324 lbs.; this force of 324 lbs. acting on the long arm of the third lever would force up the short arm with a force of 5,832 lbs.! The rule is to multiply the weight by the length of the long arm of the lever, and the product is the force it exerts on the short arm. The levers by which the power of the Columbian press is obtained are much longer than in the above example, and consequently the force which they exert on the surface of the type is much greater. The length and number of the levers employed enable the pressman, by a gentle pull at the bar-handle, to give a severe pressure to the platen.

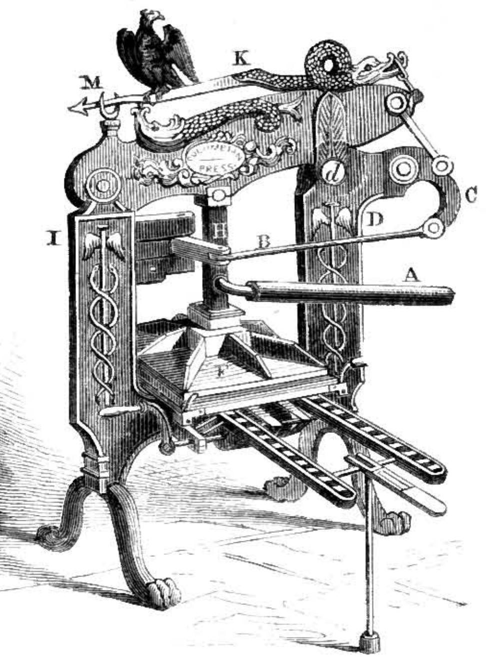
It will be understood that in all these printing-presses the type



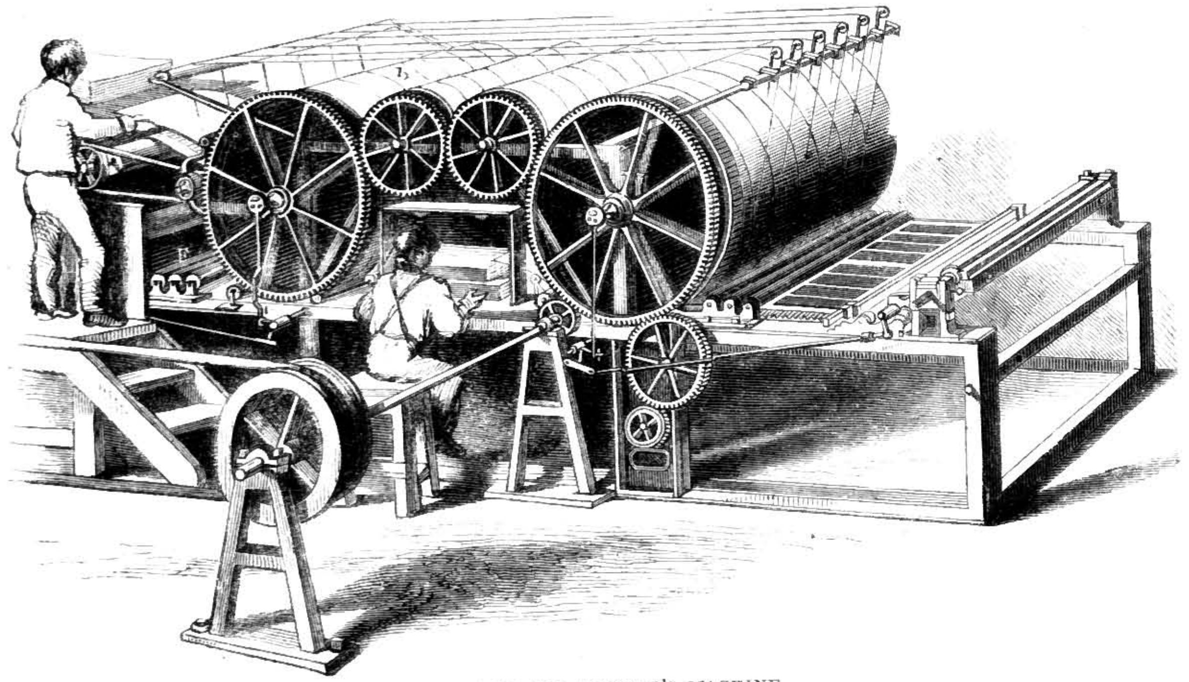
678. ARRANGEMENT OF LEVERS.



679. COMPOUND LEVER.

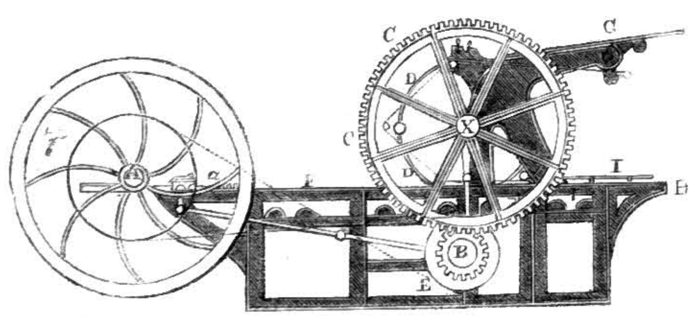


680. COLUMBIAN PRESS.

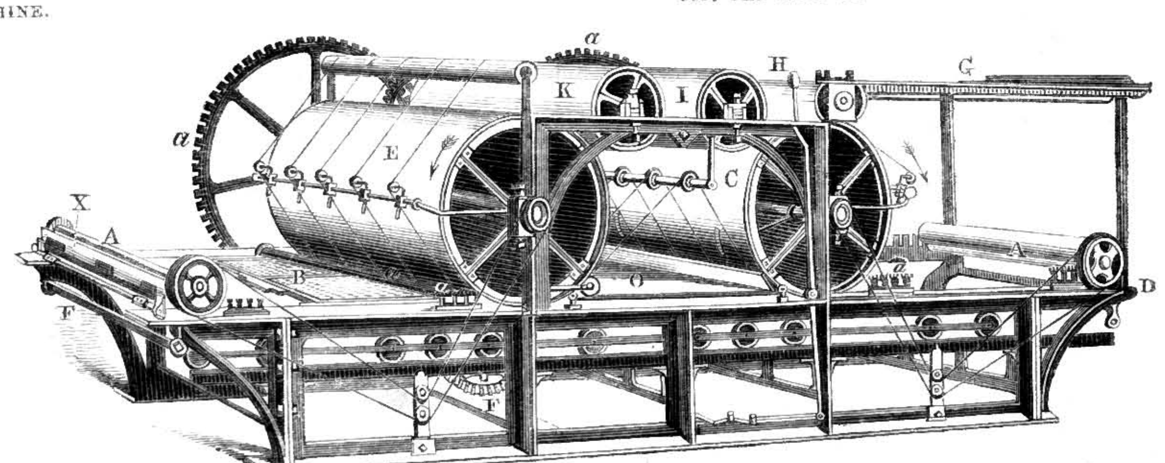


681. APPLEGATH AND COWPER'S MACHINE.

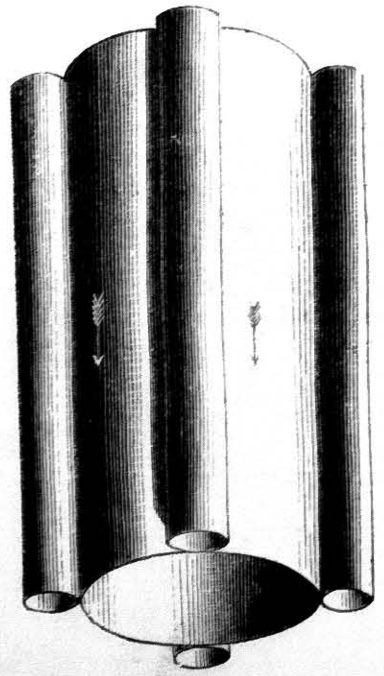
682. TEN-LINE PICA EGYPTIAN.



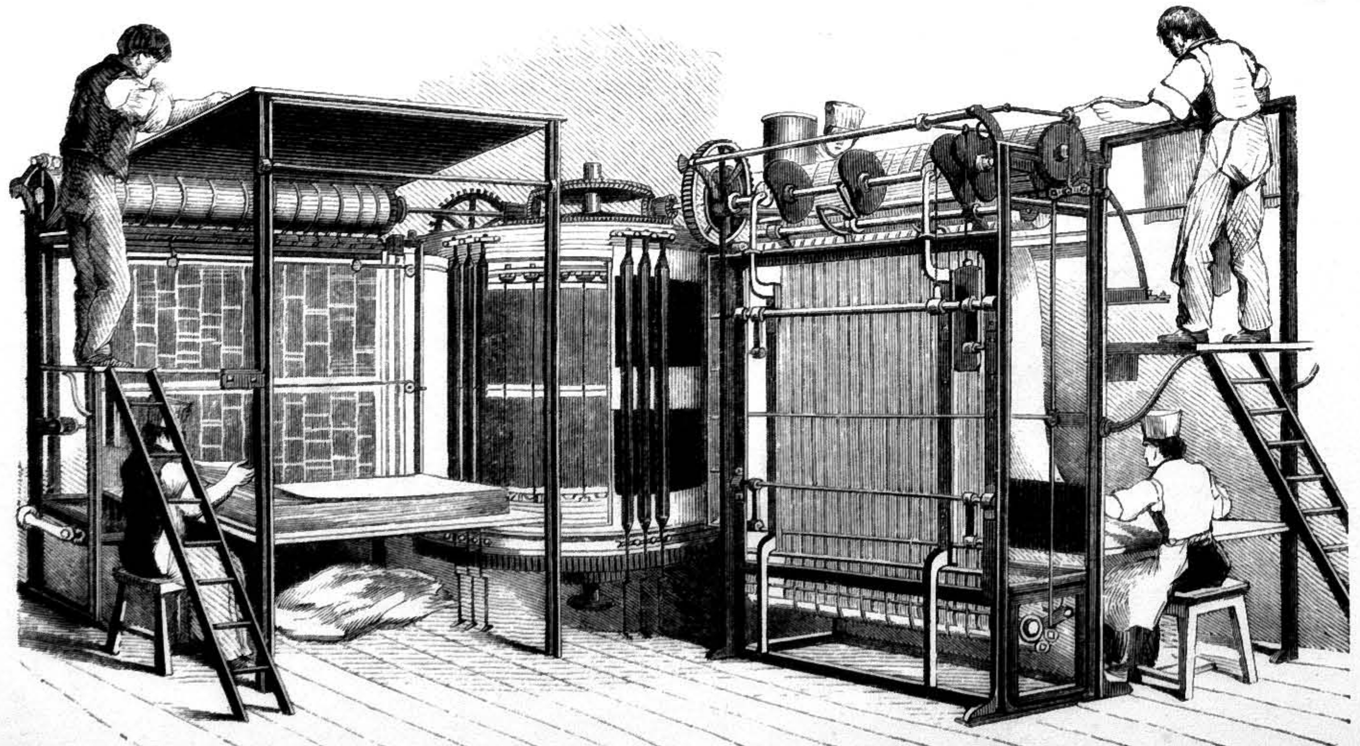
683. SINGLE CYLINDER MACHINE.



684. DOUBLE CYLINDER MACHINE.



685. PRINCIPLE OF VERTICAL CYLINDER MACHINE.



686. APPLEGATH'S VERTICAL CYLINDER MACHINE. (*Times* Printing Office.)

has to be inked by hand after every impression. The old method of inking was by means of large balls stuffed with horse-hair. These were dabbed down upon the type, and did the work in a very inconvenient manner: they were superseded by Professor Cowper's *inking-table* and *roller* (figs. 660 and 661), in which *A* is a large reservoir of ink; *B* a handle and cylinder, by turning which the ink is spread out; *C* the surface on which the inking-roller, having been supplied with ink by the cylinder *B*, distributes it. *D* is the inking-roller, which, being supplied equably with ink from the surface *C*, is rolled over the type. While one pressman is removing one sheet and laying on another, the second inks the forme again by running the roller over it. Two men can in this way print 250 sheets an hour on one side only. The whole number of sheets having been thus worked off, they proceed to work the second forme, or to print the sheet on the other side, which is called *perfecting*. The pages are kept back to back, or *in register*, by placing the points which hold the sheets on the tympan through the same holes in the centre as were used in printing the first side. When both sides are printed the sheets are hung up in the warehouse to dry; and as soon as the ink has hardened they are separated from each other and placed between sheets of thin glazed millboard, and subjected to the powerful pressure of a hydrostatic press, or of a *screw press* (fig. 669), in which *A* are the glazed boards, and *B* wooden boards to assist the screw. The object of this pressure is to remove the indentations formed by the type in the paper, and to give the paper a smooth, finished appearance.

In spite of all the improvements in the printing-press it remained, and still remains, defective in two essential points. It is very slow, and great strength is required in working it. Only two men can work at it together, and these two cannot print more than 250 impressions an hour of what is now a small-sized sheet; that is, 2,500 impressions a day, on one side of the paper only. No man is strong enough to give the pressure required in printing some of the large sheets, such as those of newspapers. The *printing machine* was therefore required to keep pace with the demand for reading, unless, indeed, it may be said that the supply and the demand stimulated each other. The machine excels in those points in which the press is defective. It prints swiftly, and gives an enormous pressure. Instead of 250 small sheets an hour being the highest rate of printing, no less than 60 gigantic sheets are printed in a minute! This has been effected by substituting a hollow iron cylinder, or roller, for the platen or flat surface. The pressure, instead of being obtained by forcing a flat surface down upon the face of the type, is obtained by rolling a curved one over the face of the type. Again, instead of the motion being given by the strength of a man, it is now applied by a steam-engine. The result is, that there is almost no limit to the speed of printing. The faster the machine can be fed with sheets to be printed, the faster it may be worked. It has been ascertained that a man can place 1250 sheets an hour on the feeder of the printing cylinder. If, then, the feeders are increased in number, the printing may in the same proportion be increased in rapidity.

The printing machine originated with Mr. Nicholson, who obtained a patent for it in 1790; but although he suggested the principle and sketched out the details, he did not actually produce a machine. A Saxon, named König, after many failures and disappointments, succeeded in constructing a cylinder machine, in which the types were inked by a self-acting contrivance, and the paper was printed by being passed under a roller. The machine was first set in operation at the manufactory in Whitecross-street, in April 1811, and printed 3,000 sheets of the *Annual Register*, to the admiration of all persons who beheld it at work. It was, however, a very costly triumph. For in the seven years of experimenting which it had required to bring König's ideas to bear, Mr. Bensley, the printer, had spent no less a sum than 16,000*l.*

At this period, *The Times* newspaper was in existence, though it had not then become what it is now, the first journal in the world. The publication of *The Times* was commenced on the 1st of January, 1788, and it was a continuation of the *Daily Universal Register*, the first number of which had been issued exactly three years previously. Both these journals were "printed logographically," as it was styled,—that is to say, the types did not consist of single letters; but syllables, whole words, and even phrases were cast in a piece. Mr. Walter, the proprietor of the papers, had taken out a patent for this kind of printing, in the idea that it would effect a saving both of time and labour, and consequently of expense. Out of the 90,000 words which the English language contains, he had ascertained that only 5,000 were in general use, and furthermore, that a great many of these had the same root, or, to use more familiar words, were the same in body, though differing in the head and tail. Take the word USE for an example. Use becomes *dis*use, *mis*use, use*ful*, use*less*, use*fulness*, and use*lessness*. It was found, however, that logographic printing, instead of saving, wasted time and labour. Time was, indeed, saved in having words in a piece, instead of composing them in separate letters; in being able, for instance, to take up "and the," or any other phrase at once, instead of by six motions of the hand; but then much more time was lost in running to and fro, to reach the place in which the words were kept. The ordinary pair of letter cases contains 151 boxes, which hold all the different letters used in printing, separated from each other, the a's being by themselves, the b's by themselves, and so on throughout the alphabet: and the compositor, without moving from the spot on which he stands, can reach every box with ease. But the cases in which the types of logographical printing were placed contained some hundreds of boxes; the cases themselves were four in number instead of two, and they were so large that the compositor had to walk backwards and forwards to get the sorts he wanted. Mr. Walter ultimately abandoned the system as impracticable. When, however, in 1788, the paper changed its name to *The Times*, and in the hands of Mr. Walter's son was managed with so much talent that the demand for it increased, that demand could not be supplied by the common press. The pressmen took advantage of the large sale of the paper to claim exorbitant wages. At this time the experiments by König and others as to the possibility of constructing a printing machine were going on; and Mr. Walter, in 1804, seriously set to work to try and supply the place of his troublesome hand-labourers by machine labour. He was long unsuccessful: it took ten years of anxiety, inventive skill, and a large expenditure of money, before anything like success was obtained. At length, however, on the night of the 19th of November, 1814, *The Times* was printed by the machine, as was announced in that paper next day, and it was thought a great triumph to be able to print 1,100 sheets in an hour. This machine printed only one side of the paper at a time; another was soon constructed which printed both sides before the sheet left the machine. This is what is called the *perfecting machine*. But these machines were complicated, and liable to get out of order. The principle having been put in practice, the engineers set about simplifying the invention. In this they triumphed over all difficulties. The original machine contained no less than 100 wheels; the number was reduced to 10. Mr. Edward Cowper, afterwards Professor of Manufacturing Art at King's College, London, for instance, on seeing *The Times* machine at work, suggested a slight alteration, by which wheels which had cost 1,500*l.* during the experiments, were at once swept away. Gradually, printing machines were brought to a high state of perfection. They exhibit many different forms, but the same principle, that of the printing cylinder, pervades almost the whole of them. Their cost has been greatly reduced, their working rendered sure and safe, by simplifying the details, and their speed has been greatly increased. They are almost universally used for printing newspapers, and very generally for printing books. Newspapers are printed better by machine than they could be by the ordinary press; but the machine is not so well calculated for *fine* printing, so that the most beautiful books are printed by the common press; but very good work is done by the *platen* machine.

The printing machines in general use may be divided into two classes, viz.:—*Single-cylinder machines*, which print one side of the sheet; and *double-cylinder machines*, which print both sides of the sheet before it leaves the machine. A double-cylinder machine may be compared to a couple of single-cylinder machines thrown into one. Fig. 683 represents the principle of a single-cylinder machine; but it must first be stated how the different parts of the machine are set in motion at the same time, and at the same speed, though some of them move in different directions, and even change their directions. If the machine is to be worked by men, a handle is inserted in the axis of the large wheel *A*; if it is to be worked by steam, then the wheel is replaced by another, connected by a band, as shown in the same figure, with the shaft of a steam-engine. The wheel *A* being turned round, the cord, shown by the dotted lines, turns the cogged wheel *B*; this wheel works in the cogs of a larger wheel *C*, and *C* turns the printing cylinder *D* behind, the two latter working on the same axis *X*. The little cogged wheel also turns a universal wheel, the place of which is indicated by the shading *E*, a part of the machinery on which it works; and the universal wheel sets in motion the table of the machine on which the forme of type is placed. This table moves backwards and forwards within the framework *F*, *F*, on the little wheels beneath it. The printing is a very simple process. The sheets to be printed are placed on the board *G*; a man standing on a platform, as shown in fig. 681, moves sheet after sheet down to the top of the printing cylinder *D*, when it is caught by a cleverly contrived apparatus acting like the human hand, and it is drawn within the tapes which go round the cylinder, as shown by the dotted line. When the printing cylinder begins to turn, the table also starts from the end at which the large wheel *A* is placed; the forme inks itself by passing under the rollers indicated by *a*, and then slides towards the printing cylinder *D*: the forme reaches the printing cylinder exactly when the latter has brought the edge of the sheet to the same point; and the sheet is printed by being pressed between the surface of the cylinder and the type, as they move towards the end of the machine *H*. The tapes, which have kept the sheet close to the surface of the printing cylinder, it will be seen, are not continued round the cylinder, but end under it. Thus the printed sheet is not carried upwards as the cylinder moves upwards, but is thrown off on the board *I*, and the forme passes under the board. While that part of the cylinder on which the grippers are placed is rising to roll round another sheet, the table has shot back to the opposite end of the machine, the forme obtains another supply of ink, and shoots back again, reaching the printing cylinder the very instant that it has brought down another sheet to be printed, as already described. This ingenious motion, forwards and backwards, is caused by the working of the universal wheel under the table.

Fig. 684 is a representation of a double-cylinder machine. The moving-wheels are at the back instead of the front, as in the representation of the single-cylinder machine. *A A* are the inking-rollers, which supply the formes with ink; and there is a set at each end of the machine, outside the large printing cylinders. The type is inked by the rollers *a a*. *B* is the forme of type for printing one side of the sheet: the second forme, for printing the second side, cannot be shown, as when one forme is drawn out in the position of *B*, the other is drawn under the cylinder *C*. The formes glide backwards and forwards, *B* under cylinder *E*, and the other forme under cylinder *C*, on a table similar to that of the common press, the table being set in motion by a wheel *F*. The moving machinery is indicated by the cog-wheels *a a*. A man stands on a platform with the sheets to be printed lying on a board *G*; he moves sheet after sheet downwards, until its edge meets the roller *H*, the end of which is just seen, and the sheet is caught within a series of endless tapes, which are shown by dotted lines extending throughout the machine, but they are too complicated to be clearly explained in words. These tapes, in moving in common with the machinery, carry the sheet in the direction of the downward arrow round the first printing cylinder *C*, and by the time that the sheet is half round, the bed of the machine has moved sufficiently to place the type under the cylinder *C*, and the cylinder and type move together in the direction of *O*, so that the first side of the paper is printed as it passes between them. The paper is now carried by the tapes upwards, over the cylinder *I*, and, passing under the cylinder *K*, is carried round the outside of the second printing cylinder *E*. By the time the paper is half round again, the second set of types has arrived under the cylinder *E*, and thus the second side of the paper is printed as it passes along between them. The sheet being thus perfected, is thrown out at *O*, where a boy sits to receive it. The object of the cylinders *I* and *K* is simply to convey the sheet smoothly from one printing cylinder to another. But how, it may be asked, is the sheet turned while it is passing through the machine to allow of its being printed on both sides?—By making the printing cylinders turn in opposite directions, and thereby passing the sheet down the outsides of them. If the sheet passed down the inside of the second cylinder *E*, the printed side would be presented to the second forme of type: but by passing it outside, the paper is really reversed, and the unprinted side is presented to the type. It is difficult to explain this in words; but any one may see it clearly by taking a piece of paper and passing it over two rollers which are moving in different directions, in a similar manner to the printing cylinders. The printing machine exhibits some other beautiful contrivances for the regulation of its working; but it would be impossible to represent them in an engraving, and they must be seen to be understood.

The speed of a single-cylinder machine is, on the average, about 1,000 sheets an hour, and of a double-cylinder machine about 750 sheets an hour printed on both sides. The speed, as we have said, is limited by the power of feeding the machine with paper, and few men can lay on more than 1,250 sheets an hour. But a far greater speed has been attained by increasing the number of cylinders. For instance, Messrs. Applegath and Cowper constructed for the proprietors of *The Times* a machine which may be regarded as four machines in one. It had four printing cylinders, four feeding places, and four places where the printed sheets were thrown out, and the speed attained was 4,000 impressions an hour.

But even this speed has been outstripped. The circulation of *The Times*, the name of which is inseparably connected with the progress of machine printing, had grown so large that it became necessary to print it quicker than ever. The proprietors had recourse to Mr. Applegath, an engineer, who had done more than any other person for the improvement of the printing machine; and he constructed one the simplicity of which is admirable, while its speed is practically without limit. It is a cylinder machine (fig. 686), but instead of the cylinders being placed horizontally as in the machine already described (figs. 681, 684), they are placed vertically,—that is, like a drum standing on one end. The type is also fixed on the surface of the central cylinder, which turns round continuously, instead of being placed on a bed or table moving backward and forward under the printing cylinders. Before we proceed to give a particular description of this wonderful machine, we may perhaps be able to convey a rough idea of it by the diagram fig. 685.

These cylinders represent the cylinders of the machine. It must be borne in mind that they stand upright like so many columns, the opposite ends pointing towards the ground. The types to be printed are fastened on the surface of the central cylinder *A*, and the whole of the cylinders turn round in the same direction. The small cylinders are really the printing cylinders. A sheet is put in at each of the places marked by the arrow, it is drawn in by the motion of the machine and pressed against the large drum, and is thrown out on the other side printed. Of course, it is so arranged that the type on the great cylinder shall arrive opposite each small cylinder at the instant that it is fed with a sheet of paper.

What we have just written simply illustrates the principle of the new printing machine. We will now endeavour to convey an idea of its details, taking for our example the superb machine by which *The Times* newspaper is printed. A large central cylinder or drum is erected, capable of being turned round on its axis. Upon the sides of this drum are fixed the columns of type by which the

newspaper is printed, running straight up and down. The drum is 200 inches in circumference and 66 inches in diameter, and, therefore, the curve formed by its surface is so easy that the types stand almost square on their feet. The great drum is surrounded with eight smaller drums or rollers, also placed with the axis vertical,—that is, like so many columns standing upright. Each of these cylinders is connected with the great drum by toothed wheels in such a manner that their surfaces must move at exactly the same rate as the surface of the drum. They are, in other words, so connected, that they can only move together and at the same speed. The printing is effected in this way. The drum and cylinders are set in motion; and in moving, the types on the surface of the drum become inked, and the eight cylinders are supplied with paper. The drum in passing round presses the type successively against each of the eight cylinders, and thus in turning round once eight sheets are printed.

Let us now explain how the type is inked eight times whilst the drum is turning round once: and how the eight cylinders are supplied with paper. Beside each of the eight paper cylinders are placed a set of inking rollers; near these are placed two ductor rollers. These ductor rollers receive a coating of ink from reservoirs placed above them. An inking table is attached to the great drum, and, as it passes, receives a coating of ink from each of these rollers. The inking table next meets the rollers which ink the type, and transfers the coating of ink to them. Next, the types pass along, and encountering the inking rollers, receive the ink in turn. Next, the types encounter the paper on the cylinders, and thus they are printed. In a single revolution of the great central drum, therefore, the inking table receives a supply twice successively from the ductor rollers, delivers over that supply eight times successively to the inking rollers, which in their turn deliver it eight times successively to the faces of the type, from which it is conveyed finally to the eight sheets of paper upon the eight cylinders.

It remains to be explained how the eight cylinders are supplied with paper. Over each of them is erected a sloping desk, upon which a stock of unprinted paper is placed. An attendant standing by the side of the desk pushes the paper, sheet by sheet, towards an apparatus known as the *fingers* of the drum. These fingers, seizing the sheet by the edge, draw it straight down in a line with the drum, just as we draw down a window blind; and when it has descended sufficiently, a self-acting frame moves it sideways instead of downwards, and it is carried between tapes towards the printing cylinder. As it passes round the printing cylinder the types have been moved round sufficiently to print it. The sheet is then carried back, still sideways, by the same tapes on the other side of the frame, until it arrives at another desk upon which it is received by another attendant. It may be stated here that one of the difficulties which Mr. Applegath had to encounter in the construction of this machine was so to regulate the self-acting parts that the impression of the type should always be made in the centre of the page, and so that the print on one side of the paper might come exactly back to back with the print on the other side. This is generally accomplished, though an occasional deviation will occur. The type fixed on the drum moves round at the rate of five feet per second, and the paper to be printed is moved in contact with it, of course, at exactly the same rate. Now, if by any error in the placing of a sheet of paper, or in its motion, it should arrive at the printing cylinder so little as $\frac{1}{60}$th part of a second too soon or too late,—that is, before or after the type has arrived opposite the printing cylinder,—each column will be printed $\frac{1}{60}$th part of five feet out of its place; that is to say, one inch. In that case the edge of the print on one side of the sheet would be an inch nearer to the edge of the paper than the print on the other side. Such an incident rarely happens, but when it does the sheet is spoiled. Still the waste from the slipping of the sheets is considerably greater in the horizontal machine, than in the present vertical machine.

The movement of the vertical machine is round and round again without interruption. *The Times* machine prints no less than eight sheets at every revolution. The moment that one sheet is drawn into the machine, space is left for another, which the attendant immediately supplies, and in this manner the machine receives from him two sheets in every five seconds. As the same thing takes place at each of the eight cylinders, sixteen sheets are drawn into the machine and printed every five seconds. *The Times* machine prints between 10,000 and 11,000 sheets an hour with ease; but if the men who place the sheets are very expert, it will work off from 12,000 to 13,000 an hour. Indeed, the rapidity of the machine is limited only by the power of the men to feed it with paper. If still greater speed were required, it might be obtained without changing the principle of the machine. It would only be necessary to increase the size of the great central drum carrying the type, so that a larger number of printing cylinders might be placed round it. If, for instance, a machine with eight cylinders will print 10,000 sheets in an hour, a machine with sixteen cylinders would print 20,000 in an hour.

Since this machine has been at work so successfully, an American machine has excited attention as being still more productive. The chief variation in its principle is in making the printing cylinder horizontal instead of vertical, so that the paper is introduced in the same position or nearly so in which it is printed; whereas in Applegath's machine, the position of the paper has to be changed from the horizontal one in which it feeds the machine to the vertical one in which it is printed.

The benefit arising from machine printing is incalculable. The machine has relieved men of hard toil which was often hurtful to health. Sheets of a greatly increased size can now be printed. The cost of printing has been greatly reduced, and the employment of printers considerably increased. The result has been an extraordinary diffusion of all kinds of knowledge, and a great advance in the civilization of the world.

It is a remarkable fact that a portion of the impression of every day's *Times* is printed in *stereotype*. The type is set up as usual for the advertisements and other matter, when a cast of it is taken in a pulp in which paper largely enters. This produces a sharp, clear impression, which is placed in a mould exactly adapted to the curvature of the printing cylinder, and melted stereotype metal being poured into it, an exact counterpart of the type is produced in a solid plate, the whole operation being performed in about half an hour. The plate is then screwed on to the printing cylinder, and when it has done its work, it can be melted up for the next day's service. It is usual, however, to take two casts of the same plate in case one should crack or break during the rough working of the machine; and it is this rough working which causes the rapid wear of the type, and originally suggested the stereotyping of a portion at least of the formes.

The art of stereotyping is usually applied to books of a permanent character, for which there is a steady demand. Its advantages are chiefly twofold: it saves the publisher from printing a very large impression, which would require considerable warehouse room, and this in London is not a small item of expense; and on the other hand, should the publisher prefer to print a small impression of a book, he can do so by stereotyping, and thus save the costly process of setting up, correcting, &c. the work, every time he wants copies. Stereotyping is now so easily and quickly accomplished, that it is becoming more and more adopted. Electrotyping is also much used. In this process an impression, say of a page of type containing wood-cuts, &c. is taken in wax, by putting the page of type upon the bed of a hydraulic press, placing the wax on the type, and pressing the two together. The impression, which is quite sharp and distinct, is brushed over with plumbago powder to make the surface a conductor: it is then placed in a bath of sulphate of copper, so as to form one of the terminal plates of a voltaic current. This produces a decomposition of the sulphate, whereby a crust of pure copper is deposited on the plumbago surface. This crust can be easily detached, and as it is not thicker than writing-paper, it is strengthened by pouring melted type-metal on its back surface. Its front is a *facsimile* of the type, wood-engravings, &c., and can of course be printed from.

XXXIII.—THE BOOKBINDER.

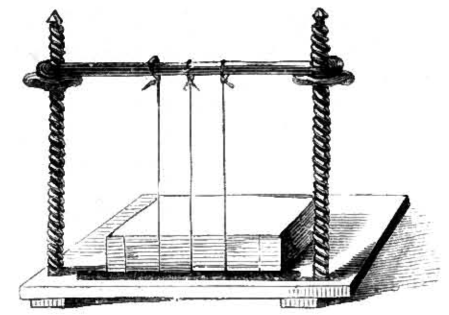
Although the art of bookbinding is strictly a trade, inasmuch as its operations are almost entirely confined to the labour of the hand, assisted by appropriate tools, yet in the magnitude of its operations it rivals the dignity of a manufacture. Readers are now so greatly multiplied, and the price of books is so much lessened, that editions which a few years ago could be reckoned by single thousands are now counted by tens of thousands. The binder has had to contribute his share to the cheapening of books, and he has succeeded in doing so by a skilful division of labour, and bringing into one large building branches of the trade which before were scattered. The introduction of cloth binding instead of leather has also greatly cheapened the binding of books, and as an example of the celerity of the binder's work, we may notice that while the earlier operations of folding, sewing, ploughing, &c., are going on in one part of the building, the cloth boarded covers, with their embossing, gilding, &c., are being prepared in another. Indeed, an edition of several thousand books sent in quires to the binder's on Monday morning may be delivered *bound* on Wednesday evening.

In printing a book, the sheets of any particular signature, A, B, C, &c. are collected together to the full number of the impression,—that is, all the sheets marked A are together, the same with the sheets B, &c. Now the first step preparatory to binding is called *gathering*,—that is, a man takes a single sheet from signature A, another sheet from signature B, a third from signature C, and so on until he has got a complete copy of the work in sheets. It is more usual, however, to begin the gathering with the last signature; that is, supposing the signatures to extend from A to Z, taking a sheet of Z, placing upon this a sheet of Y, and so on up to A. All these gatherings are folded into *quires*, and in this state are delivered by the printer to the binder.

The first operation at the binders is *folding*. This is done by females, with the assistance of a folding-stick or paper-knife, taking care that one page shall be exactly opposite to another in each sheet, and that the signatures follow properly. A good folder will fold 400 or 500 octavo sheets in an hour. The folded sheets are next put into a hydrostatic press, for pressing them into a compact form and improving the surface of the paper. The old plan (still adopted by small binders with books not recently printed) was to beat the sheets on a large smooth stone, with an iron bell-shaped *hammer* (fig. 701), weighing twelve or fourteen pounds. This plan was to a great extent superseded by passing the sheets between iron rollers, which did the work in one-twentieth of the time required by the hammer. Care must be taken in all these methods, especially with new books, that the ink of one page does not *set off* and disfigure the opposite page, which it is very liable to do.

The next operations are to collate each book, to see that the signatures run properly; to insert engravings, if any, in their proper places, and to add the waste leaves at the beginning and end. The back and head are then knocked up square, and the book is enclosed between a couple of pressing boards, with the back projecting a little way. The workman then places the boards with the sheets between them, between the jaws of the *cutting-press* (fig. 700), and passes a tenon saw across the back so as to make a number of grooves for receiving the cords or *bands*, for holding the threads in the sewing, and also for securing the boards of the covers. There is also a groove at each end for what is called the *catch* or *kettle* stitch. The sheets are then passed to the *sewing-press* (fig. 687), in which it will be seen that the top rail holds three *bands* or strings, and they are made tight by being twisted into brass *keys* (one of which is shown at fig. 698), which pass through a groove below the flat board or basis of the press. The sewing is done by females, and the commonest kind, called *up and down work*, consists in taking two sheets at a time and passing a thread through the grooves of each alternately. For example, the sewer passes the needle through the top kettle-stitch of the lower sheet, then out above the first band, and then into the upper sheet below the first band, then out above the second band, then below this band into the lower sheet, then out through the kettle-stitch of the lower sheet, then lastly this lower sheet is secured to the previous sheet by passing the thread round its lower kettle-stitch. Two more sheets are now taken, and the same routine is gone through. In some kinds of fine binding, the sheets are sewed all along and only one at a time, the thread being passed round every band. To prevent injury to the book, tapes are sometimes used instead of strings, and no grooves are sawn for the bands, for the holes thus made gradually enlarge in size as the book is used, and the only holes made when tape bands are used are those of the needle.

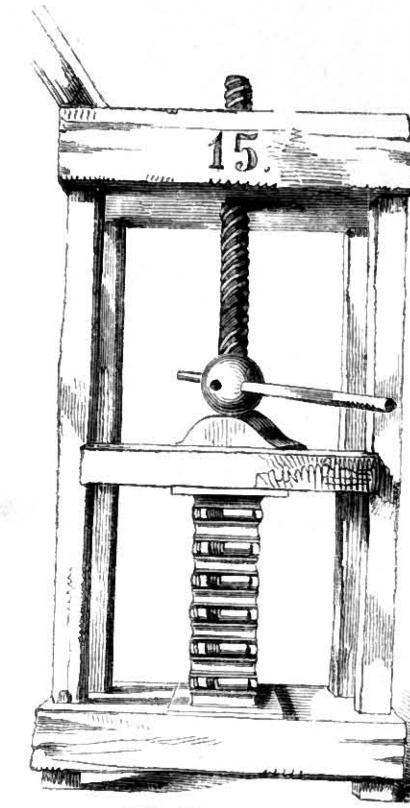
The folding and sewing are done by females; the rest of the work by men. The sewing is secured by brushing glue over the back of each book and covering this with a shred of paper or coarse, thin canvas; the latter, for certain kinds of binding, projecting in flaps at the sides for the purpose of holding the boards. When the glue is dry, the book is placed between a couple of boards with the side and bottom edges projecting, and these are cut off with a large knife: the folds of the sheets are not cut through, only a portion of the projecting uneven edges. The back is next rounded by placing the book flat, drawing the back on one side, and gently tapping it with a *broad-faced hammer* (fig. 699); the book is turned over and tapped on the other side, the effect of which is to make the back convex. The book is then placed between a couple of boards in a *screw-press* (fig. 700), with the back projecting, and is hammered so as to cause a ridge to project over the board on each side for the reception of the boards or side covers. The books are now ready for placing in their cases, which being done, the outside fly-leaf is pasted to the inner surface of the boards, and the books are built up with wooden boards into a pile and placed in a *standing-press* (fig. 692), where they undergo compression for some hours. The solid substance of the cases consists of mill-board, which is supplied to the binder in large sheets, and cut by him to the required size. Supposing the cover to be of cloth, this is cut out and stamped by means of embossing and other presses with the various borders and devices required. The binder receives the cloth in rolls or pieces each 40 yards long and 36 inches wide. The cloth is cut to the proper size of the cover with an extra quantity for overlapping, and the inside of each piece being covered with glue, the two mill-boards are placed upon it, at the distance required by the thickness of the book. A strip of paper or canvas is placed along the inside between the two boards; and the projecting edges of the cloth are folded in, and the whole is well rubbed down. In this way two men will make 100 covers in an hour. When the covers are dry, they are embossed and gilt. Such ornaments as are produced by pressure are called *blind-blocking*, and when done by hand *blind-tooling*, while the gilt ornaments and lettering are called *gold-blocking* or *gold-tooling*. Both descriptions of ornament are applied by means of *blocking-presses*, in which a plate or block of brass, with the ornamental pattern for the back or sides cut upon it, is fixed in the upper bed of the press and kept hot by a row of gas jets burning in a cavity of the upper bed. The cloth cover being inserted in the lower bed, a man with a long lever swings round the screw, and brings the upper bed with great force upon the cover, so as to emboss the impression. The cases then go to the gilders, who cover the parts intended to be gilt with a thin layer of white of egg called *glaire*, and then with leaf gold. The covers are now passed to a gold-blocking press, which resembles the embossing press just described, only less force is required; the cover being introduced into a properly adjusted bed, the heated brass block is brought down by means of a lever on the cover, with a gentle and equable pressure, which fixes the letters or device. As the covers are



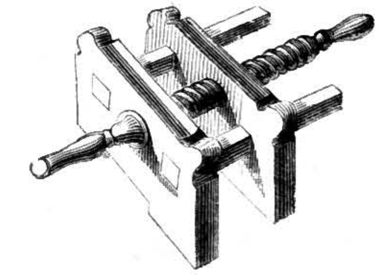
687. SEWING PRESS.

688. GOLD LEAF BOOK.

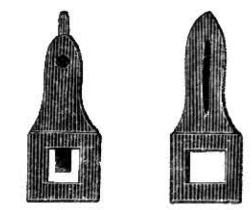
689. BLIND TOOLING BLOCK.



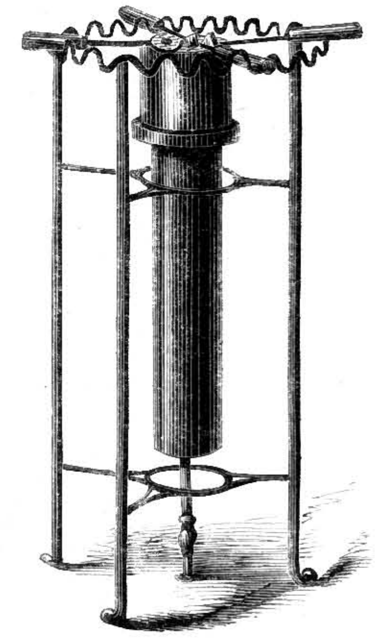
692. STANDING PRESS.



690. PLOUGH.

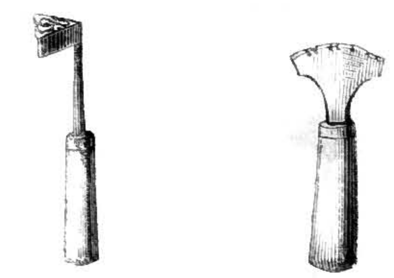


691. CUTTING BLADE OF PLOUGH.



693. GAS STOVE.

694. WORKSHOP.

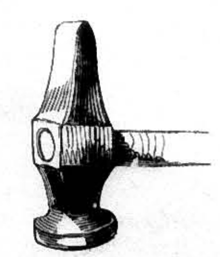


695. TOOLING INSTRUMENTS.

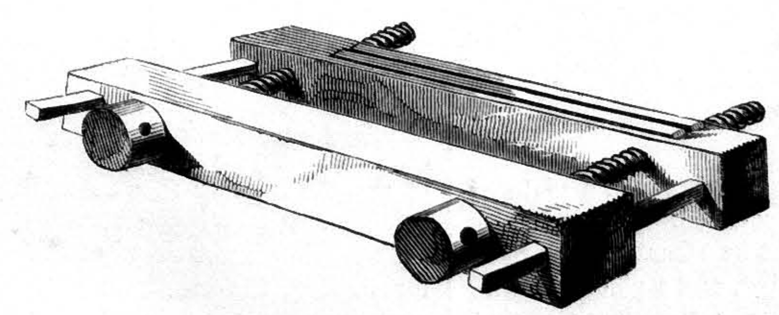
696. LETTERING TOOL

697. POLISHING IRON.

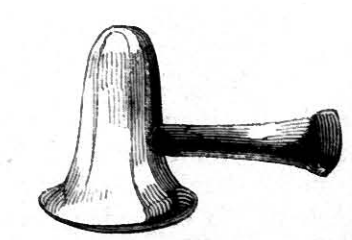
698. BRASS KEY.



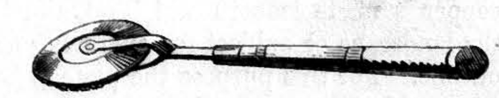
699. TOOLING HAMMER.



700. CUTTING PRESS.



701. HAMMER.



702. TOOLING INSTRUMENT.

removed, the superfluous gold is wiped off with a piece of thick rag.

The foregoing style of binding refers to books bound in cloth with trimmed edges. For leather bindings the edges are not trimmed, but are cut through with a *plough* (fig. 690), so that the book does not require cutting open before reading, as in the former case. The bookbinder's plough consists of two cheeks, connected by a wooden screw, and a couple of guides; in one of the cheeks is fixed a *cutting-knife*, two forms of which are shown in fig. 691; on turning the screw, the two cheeks will be brought nearer together, and the knife attached to one cheek advanced inwards. The book to be ploughed is placed between wooden boards in the *press* (fig. 700), with the edges projecting, and one of the cheeks of the plough being placed in the groove of the press, the point of the knife is brought up to the book, and moved backwards and forwards against it: at the same time a twist is given to the screw, whereby the knife is advanced. The centre man in the *workshop* (fig. 694) is thus engaged in ploughing. The white edges of the book in common binding are next *sprinkled*, by dipping a brush into a mixture of Venetian red or ochre in size and water and knocking the brush against a piece of wood, so as to cause a shower of minute drops of colour to fall upon the edges. The colour is fixed by passing an agate burnisher over them, which produces a high polish. In the better class of binding the edges may be gilt or marbled. The boards, however, are first added, and secured by passing the short pieces of the bands left by the sewer through holes made in the boards. The edges, being nicely cut and secured between a couple of boards in the press, are covered with glaire, next with gold leaf, and then burnished with an agate burnisher. The marbling of the edges, and the making of marbled paper, constitute a distinct trade. The processes of the marbler are exceedingly curious and beautiful. Standing before a wooden trough containing a solution of gum tragacanth, he sprinkles upon the surface a number of colours which form disks, or blend together into veins, in a curious and complicated manner, with no art whatever of the workman, but depending solely upon the affinities or want of affinity of the colours for each other. Indeed, the art exercised by the workman rather disturbs than improves the effects produced naturally. What is called the *curl pattern* is produced by placing the pointed handle of a brush in the midst of the natural arrangement of colours, and giving it a spiral motion, whereby the colours are dragged into a spiral form. The *comb pattern* is formed by passing the handle of the brush in parallel stripes through the colour, and then passing the teeth of a comb through the colour. But whatever arrangement be made on the surface of the bath, if a sheet of paper be placed upon it and lifted off carefully by raising it by its two end corners, it will carry off the whole of the colour, and when dry requires only to be burnished to form a sheet of marbled paper, such as we see in the lining of books. This lining is inserted by the binder, and the books with their white edges being sent to the marbler, he produces on his bath the same pattern as that of the lining paper, and dipping the edges into the bath, they take up the colour without disturbing the arrangement of its pattern, and this, when dry, only requires to be burnished to fix it permanently.

The *head-band*, which serves as a finish to the top and bottom of the book, is worked or stuck on; and bands, or raised projections at the back, glued on; and then the leather, such as *calf*, *morocco*, or *Russia*, having been cut to the proper size, and the edges pared thin, is damped, covered with paste, then nicely put on, squared, and smoothed. When the leather is nicely fitted, the marbled or other lining papers are pasted down, and the book is put in the standing-press preparatory to tooling. The *ornaments* are cut out in brass, as in fig. 695, and being heated at the *gas stove* (fig. 693), are pressed down upon the leather. A long line running along the sides of the book is usually cut, of the required pattern, on the edge of a disk of brass, and being mounted on a central axis and furnished with a handle, as in fig. 702, is run along the sides of the book. Gold tooling is produced by covering the parts with glaire, then with gold leaf, and pressing the hot tool upon the covered surface, the superfluous portion being wiped off with a rag. Lettering is commonly performed by means of lettering tools, each letter being cut out in brass and mounted on a wooden handle, so that the man can spell out any title that may be required. Words in common use, such as ATLAS, VOL. &c. usually have separate tools, as in fig. 696. The binder is also furnished with polishing irons of various shapes and sizes (one of which is shown at fig. 697), which are heated and passed over the book for the finishing. Vellum binding, or that used for ledgers, account books, &c., forms a distinct branch of the trade.

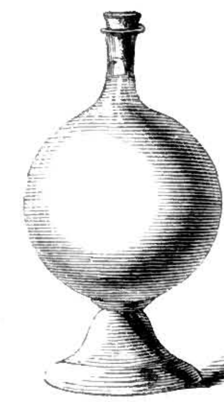
XXXIV.—THE ENGRAVER.

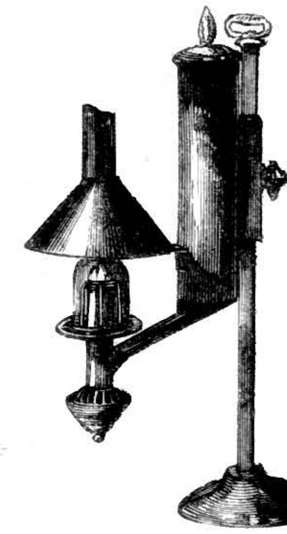
THE art of engraving affords pleasure and information, either independently of, or subservient to, that of printing. By its means the works of the most celebrated painters, sculptors, and architects may be copied and multiplied, and even inserted in books to illustrate the subject the author has written on. In this respect engraving is of great value, for there are many things which words cannot so well describe as lines.

The engraver's art separates itself into three great divisions, namely, *chalcography*, or copper-plate engraving, from two Greek words, signifying *copper* and *I inscribe*; *zylography*, or wood-engraving, from the Greek for *wood* and *I inscribe*; and *lithography*, from the Greek for a *stone* and *I inscribe*. To these may be added *photographic* engraving, in which the sun does the work, and *electro-magnetic* engraving, in which an electro-motive machine is used to move the tool.

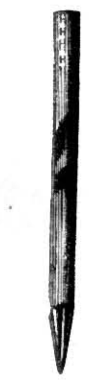
For the ordinary practice of copper-plate engraving, a plate of copper is made smooth and level, and is polished. On this plate the landscape or subject for engraving must be accurately drawn in outline. For this purpose the plate is heated, and a piece of white wax rubbed over it so as to cover it with a thin layer of that material. A careful tracing of the subject having been made in black-lead pencil, is spread over the wax surface of the plate, with the lead lines in contact with it. Pressure is now applied in such a way as to transfer the lead lines from the paper to the wax. The tracing paper being removed, the engraver goes over the subject with a fine steel point, so as just to penetrate the wax and touch the copper. The wax is then melted off; and the engraver, by means of a steel *graver* or *burin* (fig. 715), held in the hand at a small inclination to the surface of the copper, pushes the point forward so as to plough a line or furrow in the plate. The ridges or burs produced are removed by means of a steel *scraper*, but should the lines be cut too deep, a smooth tool, called a *burnisher* (fig. 719), is used to soften and rub them down. A woollen rubber is also used, with a little olive oil, to clear the face of the plate, and to polish off the bur. Writing engravers use a leather bag filled with sand as a cushion to support the plate during the work. A series of parallel lines or *tints* is usually put in by means of a ruling machine.

Engraving is not usually so simple a process as the above, except for writing, the ornamentation of silver plate, &c. Most of the engraver's work is commenced and carried on by means of *etching*, which consists in corroding by means of aqua-fortis the lines of a

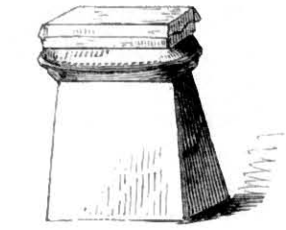

703. GLOBE.

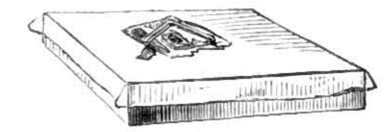

704. LAMP.


705. PENKNIFE.

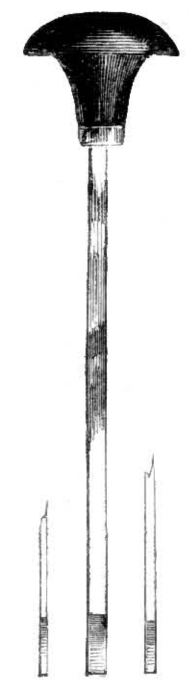

706. PENCIL.

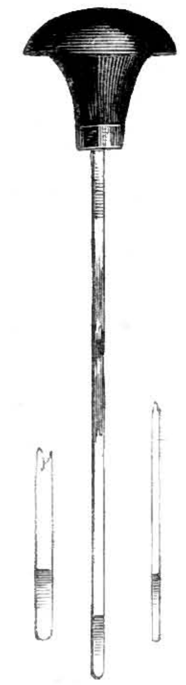

707. SANDBAG.


708. BOX, SANDBAG, AND BLOCK.

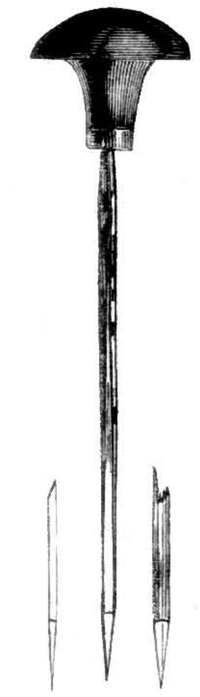

709. BLOCK COVERED UP.

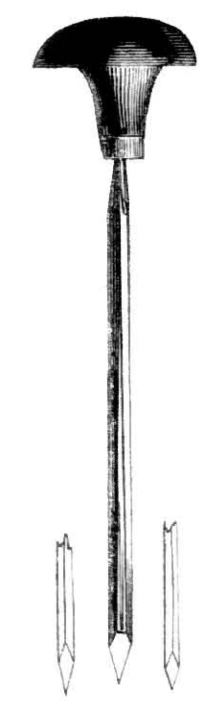

710. EYE GLASS.

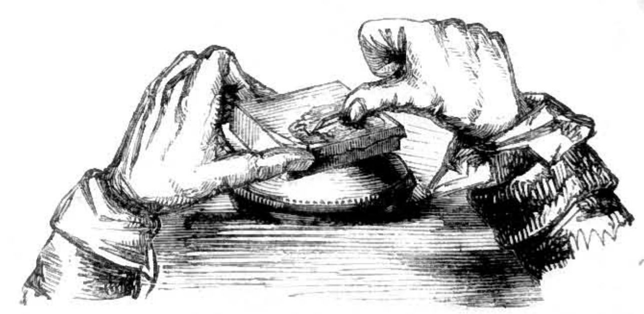

711. FLAT TOOLS.


712. SCOOPERS.

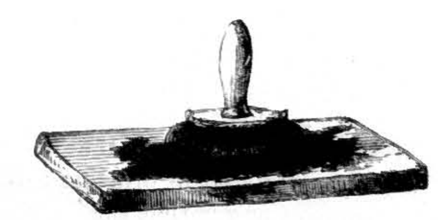

713. WORKSHOP.


714. SHADE TOOLS.

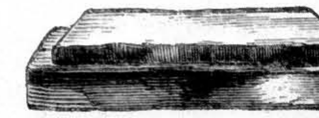

715. GRAVERS.

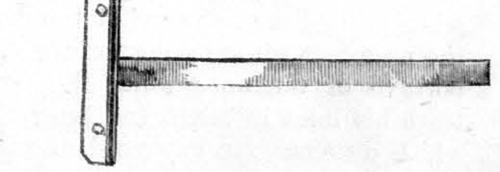

716. MODE OF ENGRAVING.


717. WAX.


718. DABBER ON SLAB.


719. BURNISHER.


720. OILSTONE.


721. T SQUARE.

drawing traced out with an etching-needle on the copper-plate, over which an etching ground of wax and pitch has been previously spread. The etching ground is made up into balls, tied up in silk, and the plate being heated, the silk is rubbed over it, and the warmth causes the substance to ooze through. The ground is equalized by rubbing it with a *dauber*, or pad of silk stuffed with wool. The etching ground is then smoked by being held over the flames of two or three candles tied together. The design made in outline in black lead on a thin piece of paper is placed face downwards on the smoked surface, and thus passed through a roller press. The subject is then gone over with an etching needle, which scratches through the ground to the surface of the copper. A border of banking-wax is put round the edge of the plate, so as to form a trough for the aqua-fortis, which corrodes the part of the plate exposed by the needle, but has no action on the wax. When the fainter and more distant parts of the subject are sufficiently corroded, the acid is poured off, the plate washed with water, and these fainter parts are covered with *stopping ground*, which prevents the acid from acting any more on those parts. The acid is again poured on, and the action renewed on the bolder parts; and this *stopping-out* and *biting-in* can be repeated so as to produce numerous gradations of tint. The wax is removed by heating the plate, and the work is finished by hand. There are various effects produced by employing different methods. What is called the *dry point* is a very fine point used for cutting or scratching the more delicate lines of skies, &c. In engraving in *stipple* the subject is executed in dots instead of strokes. In *mezzo tinto* a dark ground is raised by means of a toothed tool, and the design being traced, the light parts are scraped off from the plate, according to the effect required. In *aqua tinta* the outline is sketched, and a kind of wash is laid on with aqua-fortis, so as to produce the effect of an Indian-ink drawing. Etching on steel is done in the same way as on copper; but there is this important advantage, that steel plates can be reproduced, while those of copper deteriorate by wear. One method of multiplying is to engrave the steel plate while the metal is soft, and then to harden it by heating and suddenly cooling it. A cylinder of soft steel is then passed over the hardened plate, when it receives the impression in relief. The cylinder is next hardened, and then rolled upon a soft steel plate, by which means it transfers thereto a *facsimile* of the original engraving, capable, when hardened, of giving impressions as sharp as those of the original plate. The hardened cylinder can in this way produce a number of plates, which have only to be hardened to be fit for use. This method is now to a great extent superseded by the electrotype process, by which any number of copies of a copper or of a steel plate can be produced at small cost, and with less liability to injury of the original plate than by the former process. There are many artistic advantages in engraving on copper, and it has lately been found that the wear and tear produced by printing can be prevented by covering the engraved plate with an extremely thin coating of iron or some other metal, deposited by means of the galvanic battery.

Wood engraving differs from copper and steel engraving in having the lines raised, while in the latter case they are sunk. Box wood, from its close, dense grain, is best adapted for wood engraving. It is cut into rounds of the shape of the trunk, and of thickness corresponding to the height of the type with which it is usually associated in printing; for one of the great advantages of wood engraving is that the engraved blocks can be mixed with the type, and printed with it in the same forme. One surface of each *round* of box wood is nicely smoothed and polished, and covered with a thin wash of flake white and gum-water, and upon this the artist draws his subject with black lead pencils in reverse, so that when printed the left hand of the engraving shall appear right on the page. It is the business of the wood engraver to cut away those portions of the wood which the artist has not touched, so as to leave his lines in relief, and preserve those gradations in tint by which distances are expressed or various textures imitated. The wood engraver uses four kinds of tools, with various sizes and degrees of fineness of each kind. The first is the *graver* (fig. 715), which scarcely differs from that of the copper-plate engraver; eight or nine of these tools are required, beginning with the *outline tool*, and increasing in size and breadth. The second set of tools are known as *tinting tools* (fig. 714); they are thinner than the gravers, and ground to a more acute angle at the face, the object being that the shaving of wood may turn gently over towards the hand, and not coil over towards the point so as to hide the work. The other tools are *gouges* of different sizes (fig. 712), for scooping out the wood where depth is required, and flat tools (fig. 711), for cutting it away towards the edges. The method of holding the graver is attempted to be shown in fig. 716, but the drawing is badly done. It will be seen, however, that the force of the hand is checked by the thumb, which in large subjects rests upon the surface of the block, and in small subjects is rested against the side, the thumb being always ready to check the tool in case it should slip, for a block might be ruined if too much wood were cut away. To protect the drawing during the engraving, it is covered with paper, as in fig. 709, portions of which are torn away from time to time as the engraving proceeds. The block is supported on a *sandbag* (fig. 707), and this on a *box* (fig. 708). The engraver requires a good light, so that at night he works by the light of a *shaded lamp* (fig. 704); and to protect him from the heat of it, and at the same time to concentrate its rays upon his work, he allows the light to pass through a *globe of water* (fig. 703). The *engraver* is represented at work in fig. 713; the shade which he is represented as wearing over his eyes is objectionable, as it interferes with the circulation of the air. For very fine work a *magnifying glass* (fig. 710) is held in the eye, after the manner of the watchmaker. The man who is standing in fig. 713 is taking a proof of a finished engraving, or of one in progress, for which purpose he works a dabber on a stone with some printer's ink, dabs it upon the engraved surface, places upon this a sheet of soft India paper, and then burnishes it down with the tool (fig. 719). On raising the paper an impression will be found on it; several proofs are taken before the block is finished.

Lithography differs from copper-plate and wood-engraving in this, that the lines are neither sunk nor left in relief, but are slightly raised above the surface of the stone. The stone used is a peculiar kind of calcareous rock, which imbibes water readily, while resinous or oily substances adhere to it strongly. A drawing made on the polished surface of the stone with a resinous or oily substance will adhere to it; and if a roller charged with printer's ink, which is of an oily nature, be passed over the stone, the ink will adhere to the drawing, and not to the other parts, which have been moistened with water after every impression.

The lithographer's ink is made of tallow-soap, white wax, lamp black, and a little tallow, boiled together. The drawing chalk is made in the same manner, with the addition of a little potash. When the drawing on the stone is dry, a weak solution of sulphuric acid is poured over it, which removes the potash from the chalk, and leaves an insoluble substance behind: at the same time it slightly lowers the surface of the stone not drawn upon, and prepares it for the free absorption of water. The stone is next washed with weak gum-water, and then with water. On applying a roller charged with printer's ink, the ink attaches itself to the oily or resinous drawing, but will evidently not adhere to the parts of the stone not drawn upon, from the simple circumstance that oil and water will not mix. The stone is now passed through the press, and an impression taken, and the washing with water and the inking are repeated after every impression. A drawing or writing made with lithographer's ink on sized paper can be transferred to the stone, and printed from as before.

The copper-plate printing-press differs from the ordinary printing-press: it is what is called a *rolling press*, and consists of two parts, the body and the carriage. The body is formed of two cheeks, with proper arrangements for holding the rollers, $D\,E$ (fig. 677),

and motion is given to the upper one by means of the long levers, $C\,B$, &c. In printing a copper or a steel plate, the plate is raised to the temperature of about 180°, ink is dabbed on it, the surface is wiped with a piece of canvas, the ink is driven into the sunken lines, and cleaned off from the unengraved portions, by a skilful application of the hand, which is occasionally touched on a surface of whiting. Much skill is required in this *wiping* of the plate. The plate is now placed on the plank of the press, A, over the plate the damp paper which is to receive the impression, and over the paper two or three folds of flannel or blanket. The arms of the cross are then pulled, and the plate with its *furniture* is passed between the rollers, the equable pressure of which forces the moistened paper into the lines of the engraving, by which it absorbs the ink and retains the impression.

The lithographic press resembles the copper-plate press in several particulars, only the pressure is accompanied by a kind of scraping movement.

XXXV.—THE COOPER.

It is difficult to write concisely on the subject of any one trade, on account of the numerous branches into which it is nearly always split up. This is one of the useful results of competition; labour is subdivided, and by keeping one man to the daily performance of the same limited task, he attains to an extraordinary amount of skill and rapidity in the performance of it, the effect of which not only insures excellence of workmanship, but cheapness of production.

Few trades are more subdivided than that of the cooper. In the first place there is the *dry cooper*, whose business it is to make casks for holding goods that are not in a liquid state, such as sugar, flour, currants, &c. Secondly, the *wet* or *tight cooper* makes casks for all kinds of liquid goods, and this branch is again subdivided into *large work* and *small work*, and these departments are so distinct that the men who practise one could scarcely earn a living at the other. In the third place there are *white coopers*, whose business it is to make tubs, pails, churns, &c.; fourthly, the *general cooper* professes to have a knowledge of all the branches of the trade, but as he seldom excels in any one, he would find it difficult to obtain employment in any yard or shop where only one branch was practised. Fifthly, there are *back makers*, who make the large underbacks, &c. of extensive breweries, but whose work differs in many respects from cooper's work.

As the various parts of a cask cannot be shaped by the rule and the square, as in carpenter's work, and yet must fit so tightly as to be water-tight, the cooper must have an accurate eye.

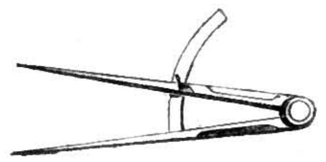
In what is called *small dry work*, the wood (generally oak or old ship timber) is sawn into lengths, and these into narrower pieces called *codlings;* these are *listed*, or reduced in size by an axe to make them narrower at the ends than in the middle, and they are then cleft by means of a cleaving-knife and a maul into staves or stave-pieces. The staves are *shaved* or *dressed*, so as to make them convex on one side and concave on the other; then *jointed*, so that when put together the joints shall be tight. The cask heads are each made of one or two pieces. The staves are brought together by means of iron truss hoops, and are made to touch at their edges at the *boulge* or widest part, but are not yet closed in at the ends. In order to enable them to bend without cracking, the staves are heated, and the hoops by which they are to be held together are driven on. A groove is cut inside the two ends of the cask to receive the head and bottom. Wooden hoops of hazel, birch, willow, ash, or other tough wood, take the place of the truss hoops, and they are usually bent, notched, and fitted by separate workmen. The practice of *small wet work* resembles the small dry, only the parts are finished and adjusted with greater care, and iron hoops are often used instead of wooden ones.

The wood used for large dry work may be beech, ash, or oak. The staves are sawn to the required length, listed, dressed on the outside, jointed, and put together with the assistance of temporary hoops, much as in the case of small dry work; but for large wet or tight work, oak is preferred: Quebec and Virginia oak for spirit casks, and Dantzic, Hamburg, or English oak for beer casks. The wood is too tough to be split into stave-pieces, but is cut by a saw in various ways, as indicated by the terms *slab-staves, tongued-staves, straight-cut-staves, doublet-staves.* The joints must be smoothly and accurately brought together by the successive processes of *listing, jointing, backing, shaving, head-making, dowelling, firing, trussing, grooving, heading*, and *hooping*, and in most cases the cask must be an exact measure—as in a barrel of beer, it must hold thirty-six gallons—all of which requires good workmanship and an accurate eye. The middle of the cask is called the *boulge*, and the space between the middle and the end is called the *quarter*. The cask should form what is called a *perfect figure*,—that is, it should form a perfect curve from end to end. A cask is called *high* or *low boulged* according to its amount of curvature from end to end. A cask which has more boulge at one part than another, is called by the workman a *lord;* and if larger at one end than the other, a *church*, or steeple-ended cask.

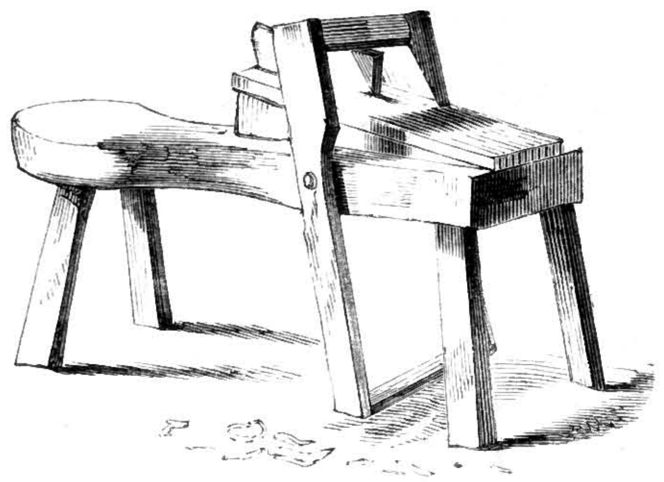
In white-work, such as tubs, pails, &c., which are usually larger at the top than at the bottom, oak or ash is generally used, and the work is smoothed on the inside as well as on the out, which is not the case with casks. Most of the work is done with a *shave*, of which there are several forms.

Back making belongs to carpentering rather than to cooperage. The bottom is set up first, and the staves are fitted in and pegged to each other, without reference to any particular proportion, for some are wide at the top and narrow at the bottom, and *vice versâ;* but the back-maker makes everything tight by accurately adjusting the size and form of the finishing or filling-up pieces.

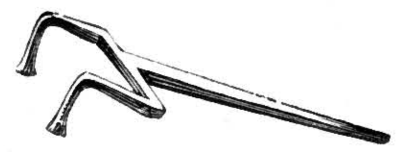
The tools used by the cooper are few and simple. They are the *axe* (fig. 741), for splitting out the staves and listing them; a pair of *compasses* (fig. 722), for measuring or *laying out* the timber after it has been cleft; the *horse* (fig. 724), on which the workman sits (fig. 731) for the purpose of dressing or shaving the staves to the right thickness. This is of wood: the man with his feet works a frame, which nips the stage and holds it firmly while it is shaved with a *cramp* knife. In shaving the staves round on the outside and hollow on the inside, the cramp knife is made slightly round at one end and hollow at the other. In jointing or preparing the sides or edges of the staves so that they shall fit well, a long plane or *jointer* (fig. 742) is used. It has the cutting part upwards, and for small staves the lower end



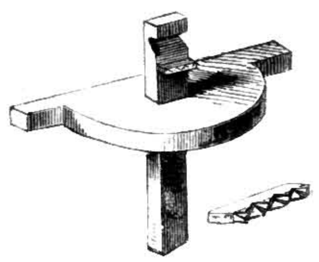
722. COMPASSES.



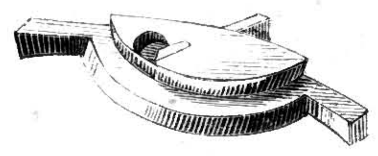
724 HORSE.



725. FLAGGING IRON.



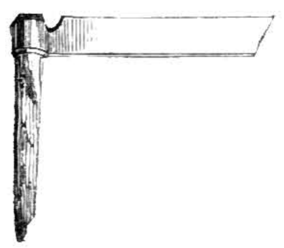
723 CROSE.



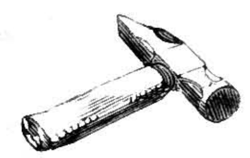
726. CHIVE.

729. ROUNDING IRON.

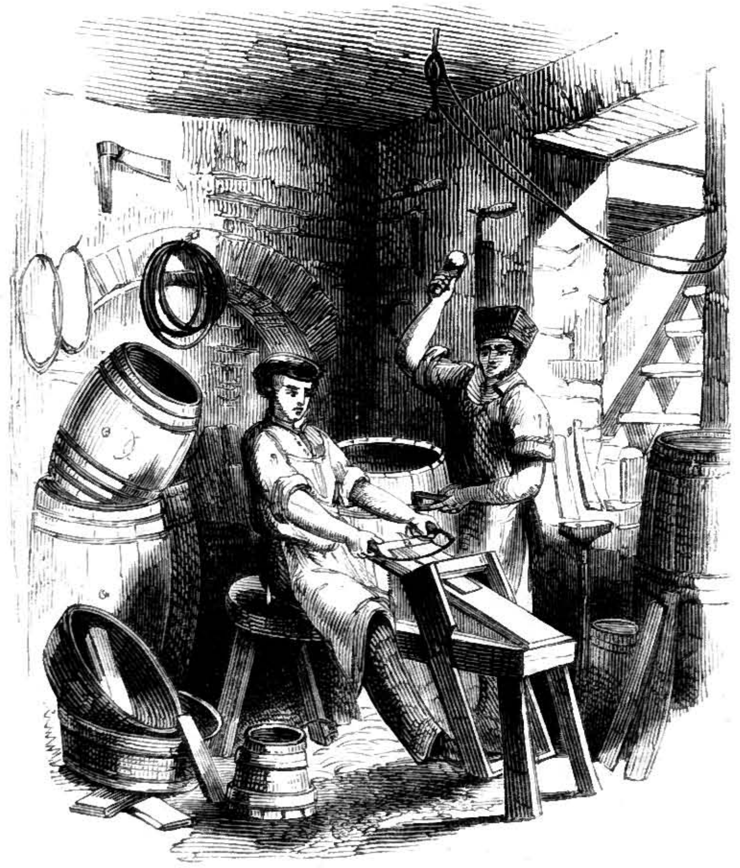
727. SPOKESHAVE.



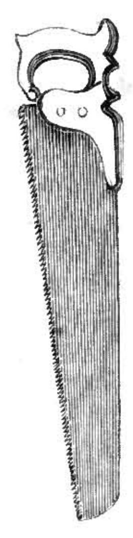
730. CLEARING IRON.



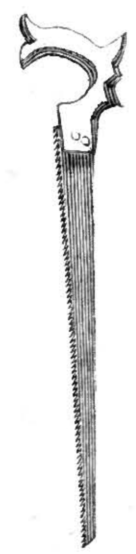
728. BEATING HAMMER.



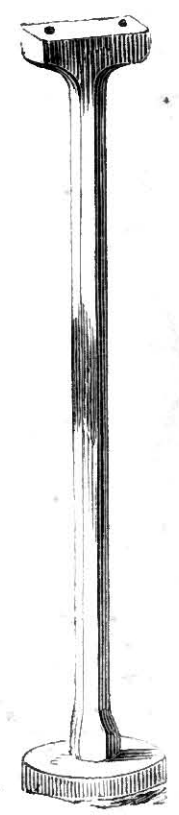
731. WORKSHOP.



732 HAND SAW.

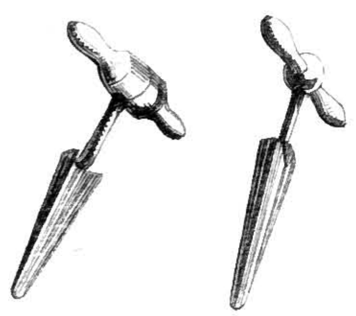


733. NARROW SAW.



737. BICK IRON.

734. DRAWING KNIFE.



735. BUNG BORERS.

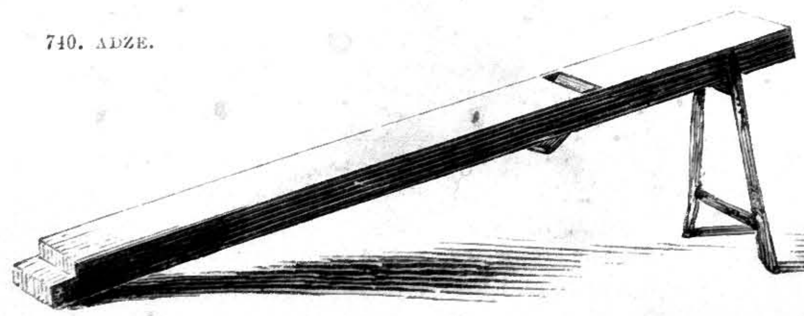
736. PUNCH.

740. ADZE.

738. CENTRE BIT.

739. DRIVER.

741. AXE AND BLOCK.



742. JOINTER.

743. TUB.

of the jointer is fixed against a bench, and for larger staves against a block in the ground or floor; the upper end is supported by a pair of legs. The heads are prepared by the *head-jointer*, which is nearly, but not quite flat. The *stave-jointer* is more or less concave, but the head-jointer is slightly convex on the surface. For wet-work the pieces of wood for the head are secured together by means of pegs, and a piece of flag or rush is inserted between the joints; and when the head is put in, joints that are too open must be flagged, and if the head be in the slightest degree too small, it should have a flag all round the groove. In inserting a flag in a joint, the joint is opened wider by means of a lever called a *flagging iron* (fig. 725), the two prongs being used on different staves and a side-pressure being exerted on the arm. The necessary *quarter*, or curvature between the centre and the end, is given to the stave by shaving from the centre to each end. In setting up the cask and bringing the edges together by means of truss hoops, six hoops for a small cask make a truss; they are called *head-hoops, quarter-hoops*, and *boulge-hoops;* larger casks have two additional quarter-hoops, namely, a *raising-hoop* and an *over-runner.* The iron hoops are formed on the *beak-iron* (fig. 737), the holes being useful in forming the rivet. In firing a keg so as to be able to bend the staves, a small *cresset* or skeleton grate, made of iron hoops, is filled with chips or shavings, and lighted: the keg or cask is then placed over or round it, and when the sap is warmed, the staves will bend without cracking. The workman then tightens the hoops by blows with the *hammer* and *driver* (figs. 728, 739), and when all the hoops are driven on, the keg is said to be *close-trussed*, or gathered in. The staves being now all bent, heat is again applied in order to set or fix them in this bent position. It is then removed from the fire, the truss-hoops are driven hard, and the ends of the keg are pared with the drawing-knife quite smooth. Then by means of a *chive* (fig. 726) he smoothes the inner surface of the end, and prepares a place for the groove. This groove is formed by means of a *crose* (fig. 723), that for kegs and small casks being called a *saw-crose*, and is used by working it backwards and forwards. The compasses are used for describing the circle for the head, and the wood is cut, first roughly with the axe, then with a hand-knife or the drawing-knife. In removing the truss-hoops preparatory to putting on the wooden hoops, the roughnesses of the wood, and the black stains left by the iron truss-hoops, are removed by the *spoke-shave* (fig. 727). In large casks the work is pared off with the *adze* (fig. 740), so as to make the sloping part of the chime of the cask. The adze is a most difficult tool to use, and equally difficult to grind or to give it the proper edge. In using the adze, the wrist should be kept as stiff as possible, and the motion be from the elbow joint.

The above particulars (for which we are mainly indebted to a little treatise in Mr. Charles Knight's "Guide to Trade") will give a sufficient idea of the trade of the cooper.

XXXVI.—THE SOAP-BOILER.

The manufacture of soap depends on certain chemical principles which have only of late years been properly understood, thus affording one out of many examples in which the useful arts preceded scientific discovery. The soap-boiler at the present day is seldom a chemist. He prepares his soap according to certain rules which have been found to succeed; but in taking account of them it is our duty to endeavour to understand them.

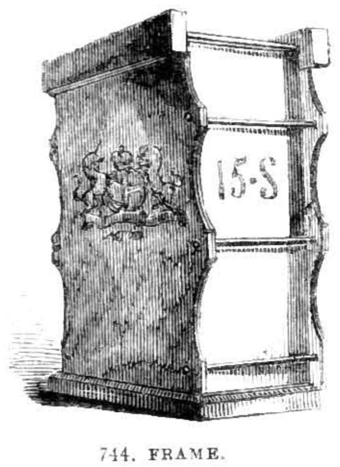
Soap is a compound of certain fatty substances with soda or potash. It depends for its cleansing action entirely upon the alkali, a portion of which, combining with the greasy matters intended to be removed by washing, renders them soluble in water. The caustic alkali would act more powerfully as a detergent if used alone; but then it would corrode many substances exposed to its action, and would destroy the colours of some goods. The *lye* obtained by filtering water through wood ashes is a solution of potash more or less caustic. By exposure to the air caustic potash and soda absorb carbonic acid gas, which converts them into mild carbonates.

Fats consist of two proximate fatty substances, namely,—*oleine*, which is fluid at common temperatures, and *stearine*, which is solid; and fats vary in softness or solidity according to the proportions in which these two bodies exist. Stearine may also contain an analogous substance, *margarine*, in various proportions. The solid fat or tallow of the sheep contains chiefly stearine; lard and olive oil contain for the most part margarine; the solid fat of palm oil is called *palmitine;* that of cocoa-nut oil, *cocine*. Now all these substances are compounds of fatty acids with a sweet substance called *glycerine:* thus, the acid of oleine is *oleic acid*, which combined with the glycerine of the oleine forms *oleate of glycerine*. Stearine contains *stearic acid*, and forms with the glycerine of the stearine *stearate of glycerine*, and so on. When stearine, oleine, &c., are mixed with the alkalies, potash or soda, they are decomposed, and their acids quit the glycerine to unite with the alkalies, while the glycerine is thrown out. The hard soaps of commerce, when made with oils (except those of the palm and the cocoa-nut), are for the most part mixtures of oleate and margarate of soda, with little, if any, stearate: when made with animal fats they are mixtures of oleate, stearate, and margarate of soda. When lime is used an insoluble soap is formed, as may be seen when washing with hard water, when the soap forms in flakes without dissolving. In such cases the carbonate or sulphate of lime of the water unites with the fatty acids of the soap, forming an insoluble compound, while the carbonic or sulphuric acid of the lime combines with the alkali of the soap.

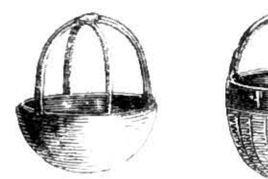
Soaps are divided into *hard* and *soft*. The former are made from fats and vegetable oils, with soda as a base; the latter from fish oil or vegetable drying oil, with potash as a base. Stearate of soda may be taken as the representative of hard soaps, and stearate of potash, which is a thick paste, of the soft. In this country, white soap is made of tallow and soda; one ton of soap takes from 10 cwt. to 14 cwt. of tallow, with a proportion of alkali which varies in different works. In Windsor soap the tallow is mixed with about 10 per cent. of inferior olive oil, and in white soap a portion of lard takes the place of an equal part of the tallow. Common rosin unites with alkalies; and when boiled with soda it forms a *pinate* of soda, which gives the distinctive character to yellow soap.

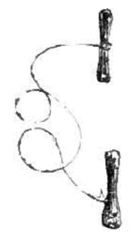
The alkali as received at the soap works is usually in the form of a carbonate; and it must be made caustic by getting rid of the carbonic acid, for which purpose it is mixed with recently slaked lime, which takes up the carbonic acid, and forms an insoluble carbonate of lime or chalk, and leaves the soda in solution in a caustic state.

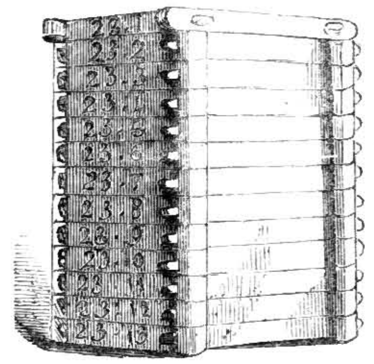
Soap is usually manufactured by one or two processes. The first is the *cold* or *small boiler process*, in which the temperature is kept below the boiling point of water, and the vessels in which it is conducted are comparatively small. The second and common method is the *large boiler process*, in which the boilers or *coppers*, as they are called, though made of cast iron (fig. 752), will each

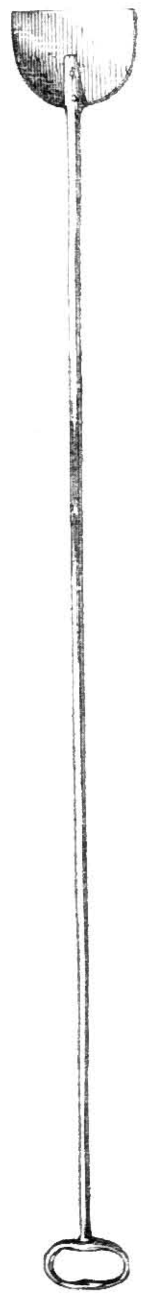

744. FRAME.


745. BUCKET.

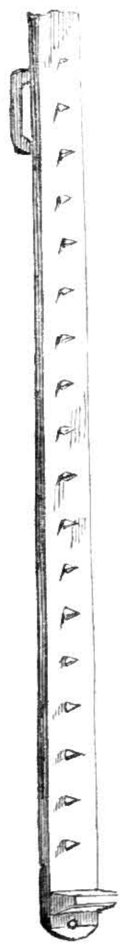

746. SWIMMERS.

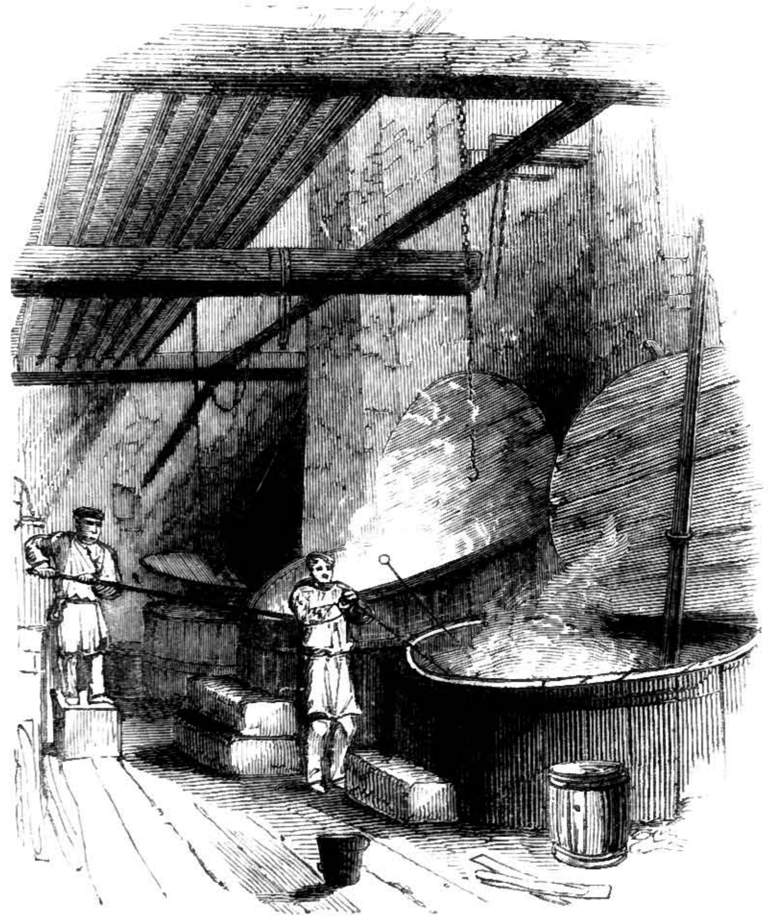

747. WIRE FOR CUTTING SOAP.

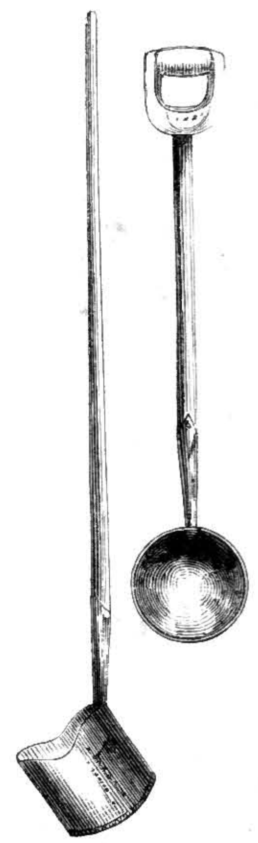

748. FRAME.

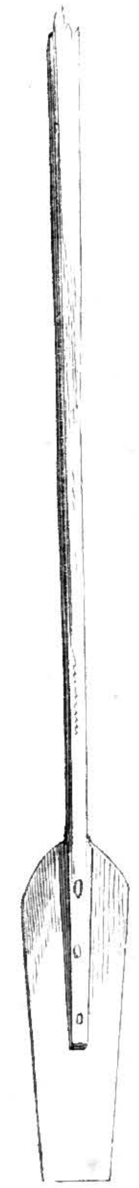

749. SCRAPER.

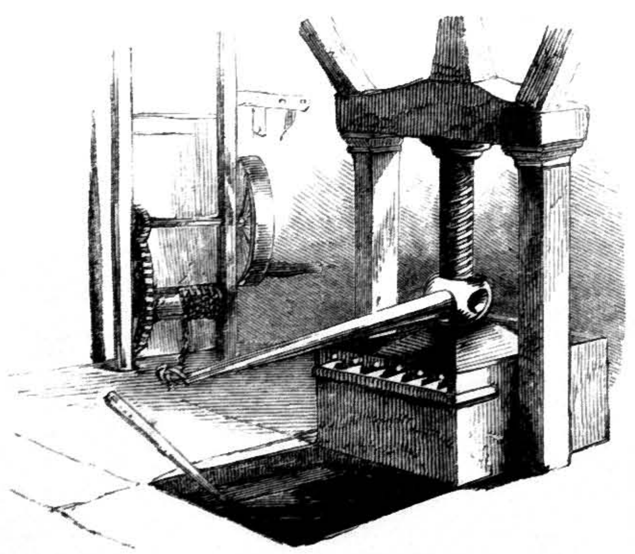

750. FORK.

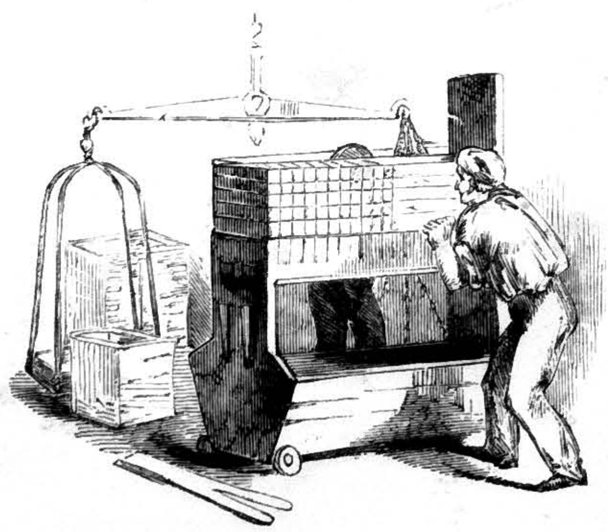

751. GAUGE.


752. BOILING HOUSE.


753. SCOOPS.


754. SCATES.


755. PRESS.


756. CUTTING SOAP INTO BARS.

hold many tons. The latter process we will briefly describe. The whole of the oil or tallow is introduced at once into the copper, but the alkali is added in separate portions. First, a weak solution is pumped up, and heat is applied until the lye ceases to be caustic. A certain quantity of salt is also added, the solution of which occupies the bottom of the copper and prevents the tallow from burning; it also has another use, which will be noticed presently. When the tallow and the lye by stirring make a uniform emulsion, the copper is allowed to cool, and the spent lye, containing some of the glycerine of the fat and the common salt, are pumped up and left to run to waste. Now it must be understood that when a soluble soap is made by boiling a caustic solution of soda or of potash with stearine, the stearate of soda or soap remains suspended in the water of the solution, together with the glycerine. By the addition of a solution of common salt, in which soap is not soluble, but glycerine is, the soap separates from the water and the glycerine, and floats on the surface. In this way the glycerine is got rid of by pumping it up from the bottom of the copper. The first boiling is called an *operation;* and three or four operations with leys gradually increasing in strength are required to produce saponification, or to "kill the grease," as the workmen call it. The tallow is known to be saponified when a small portion pressed between the finger and thumb cools into a hard cake and has acquired a slightly alkaline taste, whereas if any of the tallow remain unsaponified it will ooze out by the pressure. In making common yellow soap the rosin is added towards the end, and forms one-third or one-fourth the weight of the tallow.

When the saponification is complete, the soap is a collection of innumerable distinct globules; and to make them coalesce, a weak ley is added and the boiling is kept up for some time, large shovels or *scates* (fig. 754) being dashed into the mass from time to time (see fig. 752). During this part of the process the black impurities of the materials, called *nigre*, are allowed to subside, and *white* or *curd soap* is the result; but for *mottled soap* the mixture is left very thick, so that the nigre cannot subside. When the fire is extinguished the lid of the copper is let down, and the whole is left for one, two, or three days, according to the kind of soap, after which the semi-fluid mass is ladled out into rectangular *frames* or *sesses* (figs. 744, 748), each 45 inches long by 15 inches wide, and about 10 inches deep. They are numbered, and piled upon each other as in fig. 748, and bound by iron screw rods so as to form a kind of rectangular cistern 10 or 12 feet deep, and holding about two tons of soap. The soap cools and solidifies in the frames. The *frame* fig. 744 is of cast iron, and is used for yellow soap; fig. 748 for white or mottled. When the soap is sufficiently solidified the screw rods are removed, the frames lifted off, and the soap stands as a solid block. It is scored by the *gauge* (fig. 751), and cut by drawing a *wire* (fig. 747) through it, as shown in fig. 756. It is first cut into slabs, and the slabs into bars; these are piled away cross-wise to allow the air to circulate, and the soap is now ready for sale.

The nigre which remains in mottled soap is chiefly a sulphide of iron, caused by the action on the boiler of a little sulphide of sodium contained in the alkali. When the soap is ladled out of the boiler the nigre is equally diffused through the mass, but in draining it separates into veins, and gives the mottled appearance. *Marbled* soap is formed by sprinkling a small portion of lye strongly impregnated with sulphide of iron upon the soap just after the last boiling. *Toilet soaps* do not differ from curd or white soaps except by the addition of various perfumes, colours, &c. The vermilion or ultramarine marbling is produced by partially mixing a little of those colours with the soap in a melted state. Cakes or tablets are formed in a mould in a lever press.

XXXVII.—THE SEWING-MACHINE.

In the first edition of this work the Sewing-machine was referred to as doing a good deal of tailors' work. Since that statement was made the machine has got into such general use that almost every kind of needlework is done by its means; and the effect has been, not, as was generally supposed, to throw needlewomen and needlemen out of work, but it has actually improved the condition of persons who could earn scarcely more than sixpence a day by hand-sewing. By hiring a sewing machine, or by a number clubbing together to purchase one, they have been able to multiply their work to such an extent as to earn an easy living. This will be understood when it is stated that the sewing of a coat can be done by machine in about two hours and a half, which would require sixteen hours and a half by hand: cloth trousers, fifty-one minutes by machine, five hours and ten minutes by hand: a silk dress, one hour and a quarter by machine, eight hours and a half by hand: a plain apron, nine minutes by machine, one hour and a half by hand. Trimmings are sewn by machine at about the rate of a yard a minute.

Several attempts had been made to construct a sewing machine before the year 1846, when an American named Elias Howe took out a patent for a machine which was sent to this country, and the patent right in England was sold to Mr. W. Thomas. Soon after Howe himself came to England, and assisted Mr. Thomas in improving the invention, and after many difficulties the machine became quite successful. We hope, with the assistance of the accompanying engravings, to convey an idea of the mode in which it does its work.

Fancy a needle with the eye near the point, properly threaded, descending vertically through two pieces of cloth which are to be sewed together. Of course when the needle rises again it will leave part of the thread behind it in the form of a loop; but before the thread is drawn tight, fancy a shuttle containing a second thread to pass through the loop. If now the first thread be drawn tight, the first stitch will be made secure. Suppose the needle again to descend and to make a second loop; the shuttle again to pass through, so that when the first thread is drawn tight a second stitch is secured. But, as the needle always descends in the same place, there must be a contrivance to move the cloth forwards the distance between two stitches, so that the second stitch may not fall into the place of the first. This is done by what is called the *feed-motion*, the successful operation of which formed one of the chief difficulties of the machine. We will now see how all this is accomplished in Howe's machine (fig. 774). The machine represented is one adapted for working by hand. There are three principal movements already referred to: 1. A vertical up-and-down motion of the needle; 2. The passing of the shuttle to and fro; and 3. The feed-motion. All these motions are regulated by a cam (fig. 775) situate within the circular plate of the machine behind *H E* (fig. 774). In this cam (fig. 775) are certain irregular grooves or paths, *a*, *b*, *c*, *d*, in which projections from levers fit and work so that as the cam revolves on turning the handle the levers are set in motion. The levers that work in *a* and *b* regulate the feed-motion; the lever that works in *c* the motion of the shuttle; and the lever that works in *d* the motion of the needle.

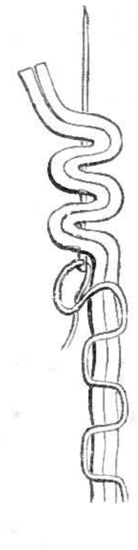
We will first refer to the up-and-down motion of the needle, the parts being shown on a larger scale in fig. 773. This up-and-down motion is produced by a lever *d a*, fig. 774, having its centre at *a* and at its short end a projection adapted to the cam path or groove (fig. 775). It will be evident that as the cam rotates upon its axis *a* (fig. 775) the lever *d a*, fig. 774, will move up and down upon its centre *a*, and thus give an up-and-down motion to the needle *n*, fig. 773, which is held by a straight bar *g g*, working in a vertical groove in the fixed part of the frame *K*, fig. 774. The lever *d*, fig. 773, has a slot or opening at its end into which fits the stump of the sliding needle bar *g g*. Near the lower *g* is a small groove and thumb screw for securing the needle *n*. It will thus be seen how the motion of the lever on its centre *a* gives a vertical up-and-down motion to the needle *n*. It will be further understood that the needle in passing through the cloth forms a loop, through which the shuttle *s* passes while the needle is rising. This shuttle is moved backwards and forwards by a straight horizontal lever, to which a backward and forward motion is given by the cam groove (fig. 775). The shuttle *s* lies on its side in a hollow space cut out from the lever, so that when the needle descends, and produces its loop of thread, the shuttle bar or lever brings forward the point of the shuttle *s*, passes it through the loop *l* into the position *s'*, leaving its thread behind in the loop. The needle in the act of rising locks and secures the stitch of two threads, preparatory to another descent. In the meantime the shuttle lever has moved the shuttle from *s'* back again to *s*, ready to pass through the next loop. All these motions may be made so rapidly as to drive the shuttle many hundred times through as many loops in the course of a minute. The shuttle and bobbin are shown separately (fig. 776); the thread that supplies the shuttle is wound upon its bobbin, and the necessary amount of tension is given to the thread by passing it through one or more of the holes in the side of the shuttle. The tension of the needle thread is brought about by giving more or less friction to the bobbin that holds it, by means of an India-rubber band that stretches from the bobbin to a screw at *F*, fig. 774. On turning the screw in one direction the India-rubber ring is tightened, and the bobbin moves with greater friction; while on turning the screw the other way the ring is slackened, and there is less friction on the bobbin. The thread proceeds from the bobbin through an eye at *B*, and then through an eye in a slotted moveable piece called a *thread lifter*, near *K*, fig. 774, and at *t*, fig. 773. The thread then passes through another hole, shown in fig. 774, to the eye of the needle. The thread-lifter has a pin in its slot, which pin being attached to the moveable piece *g g* (fig. 773) moves with it, and guides the thread-lifter up and down: by its upward motion it takes the slack out of the loop, and tightens the stitch.

We now come to the feed motion. At *e*, fig. 774, and *f*, fig. 773, are shown a portion of the feed-bar, forked at the lower end, with the needle descending between the prongs. The lower surfaces of the prongs are made rough for the purpose of assisting the friction on the cloth which is being sewn. During the descent of the needle *n* the feed-bar holds the cloth firmly down upon a plate *e*, fig. 774, which is perforated with a single hole for the passage of the needle. While the needle is rising the feed-bar moves forward through the space of a stitch at right angles to the length of the working plate, *e*, fig. 774, thus moving the work forward preparatory to another stitch. These feed-motions are regulated by two levers, the ends of which fit into the parts of the cam *a b*, fig. 775. One lever holds the work down; the other, which rocks, moves it forward. The holding-down lever has at its end furthest from the cam a spring of India-rubber rings *x*, (fig. 774), which pass from a fixed support *g* over a hook *o*, which forms the end of the holding-down lever, and presses it on a brass piece, seen near *i*, attached to the forked feed-bar. During a part of the revolution of the cam this lever is raised, and with it the feed-bar, so that the work is free to move; but during another part of each revolution the pressure is taken off the lever, and the elastic spring *x* comes into play, which, pressing the lever upon the brass piece near *i*, the forks hold the work firmly at the moment when the point of the needle enters the cloth. Before the feed-bar rises, it gives a side motion, so as to drag the work forwards through the space of a stitch. This is managed by a rocking lever not shown in the figure. It is a straight bar, with a shorter straight bar at each end, at right angles to its length. The end of the short piece nearest the cam carries an adjustable screw, the point of which enters the cam path; and by moving from a thick to a thin part of the cam, as from the narrow to the wide part of the elliptical figure *b*, fig. 775, a rocking motion is produced at every revolution. The feed-bar is also connected with the needle end of this lever, the rocking motion of which is so managed that after the needle has descended, and while the forks are pressing on the cloth, the forks, just before they rise, rock forward, and thus advance the cloth through the space of a stitch. In rising they rock backwards and descend ready to hold the work, as the needle descends to make another loop.

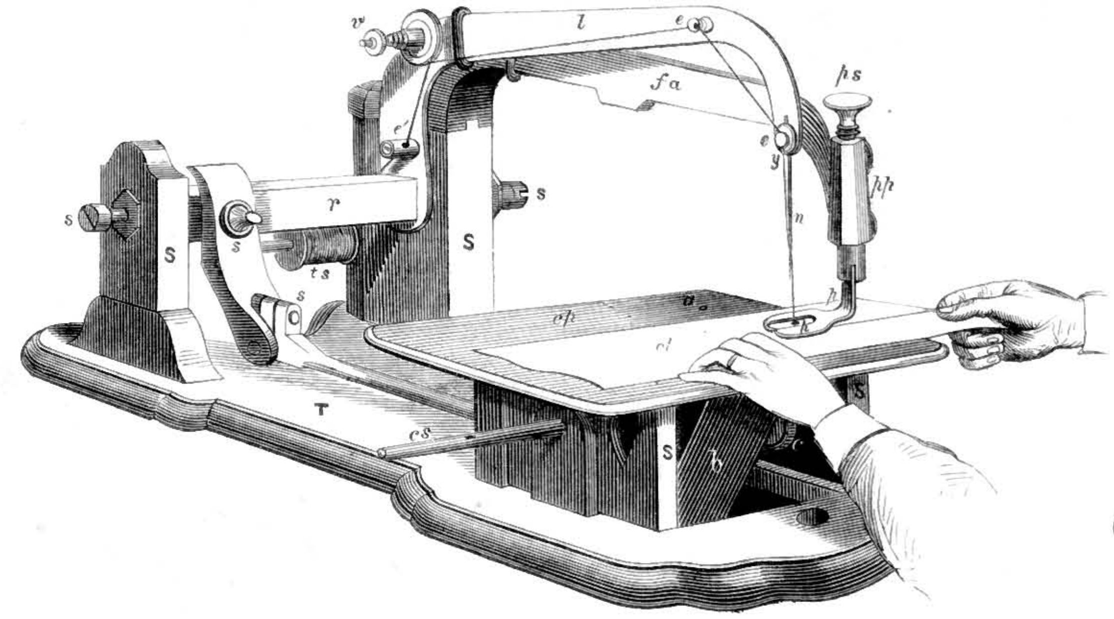
There are various adjustments and subsidiary apparatus belonging to the machine, as at *T*, fig. 774, where there is a brass slide used for keeping the rows of stitching at regular distances from the edge of the cloth, and for regulating the width of plaits or tucks. At *Y* is a thumb-screw for attaching pieces of apparatus, such as the hemmer, the binder, the braider, the quilter, &c.

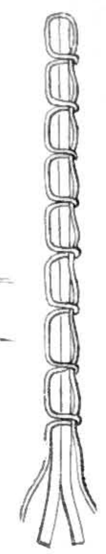
This machine is used in the Government factories, and is suited for general outfitting, and boot and shoe work. The noisy action of the shuttle is somewhat against its use in private houses, where other forms find more favour; such as the Wheeler and Wilson machine (fig. 761), in which the to-and-fro moving shuttle is replaced by a stationary one, and the locking of the needle-thread with the shuttle-thread is not done by driving the shuttle through the loop of the needle-thread, but by passing that loop under the shuttle. Attached to the end of the driving-shaft is a circular hook, which takes the loop of the thread formed by the needle passing through the cloth, carries it under the stationary shuttle, and then casts it off so as to interlock the two threads, thus forming the lock stitch. As the loop is cast off it is retained by a small brush or bundle of bristles against the outside of the hook as it rotates, and holds the loop until the hook has completed its revolution, and enters the next loop formed by the needle. The hook and brush are seen in various positions in figs. 763, 765, 766, 767. The shuttle-thread is wound upon a bobbin, *S*, fig. 768. It is formed of two discs united by a central axis, upon which and between the discs the thread is wound. This bobbin, which is about the size of a florin, fits loosely into a circular recess in the centre of the hook, and is held there by an adjustable bracket or holder, *T*, fig. 768, but not so tightly as to prevent the loop of needle-thread from passing round the bobbin. The needle-thread is kept tight by passing it round a pulley *v*, fig. 761, to which the desired friction can be given by means of a nut acting on a spring. By turning this nut in one direction the pulley acts with more friction, and by turning it in the other direction it acts with less. The passage of the thread is shown in fig. 761, from the bobbin *t s*, through the eye *e'*, over the pulley *v*, through other eyes *e e* to *y* the needle-yoke, and so through the eye of the needle *n*. At *h* is a needle-hole, *c l* the cloth to be sewn, *S S* standards, *T* the table, *c p* the cloth-plate, *s s* are screws, *f a* is a fixed arm, *p s* a cloth-presser screw, *p p* the cloth-presser piston, *p* the cloth-presser, all required to hold the cloth down. The feed apparatus will be described in another figure. The machine is worked by the foot, acting on treadles, which set in motion the endless band *b*, fig. 761, and *b*, fig. 770.

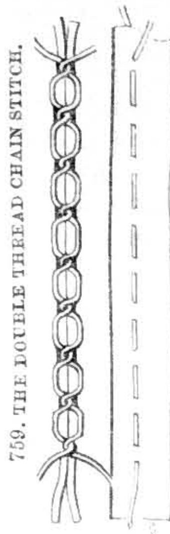
On working the treadles with the foot, the parts set in motion perform the following functions. The needle descends through the cloth, and in the act of rising forms the thread into a loop, as in fig. 763; the thin-pointed portion of the hook enters this loop, and by its rotation enlarges it, passes the shuttle-thread through it, and becomes twisted round it; as the hook continues to revolve the loop with its shuttle-thread comes round to the open part of the hook, escapes to the outside, and is held there by the brush *c*, figs. 765, 766, 767, until the hook has entered another loop, at which moment the brush comes opposite a hollow cut on the outside of the hook, as at *b*, fig. 765, when the loop escapes, and is drawn up by the motion of the hook in enlarging another loop, so that the second loop is formed for the most part from the first with the addition of

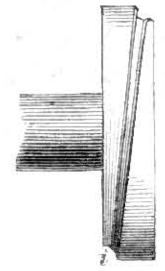

757. THE RUNNING STITCH.

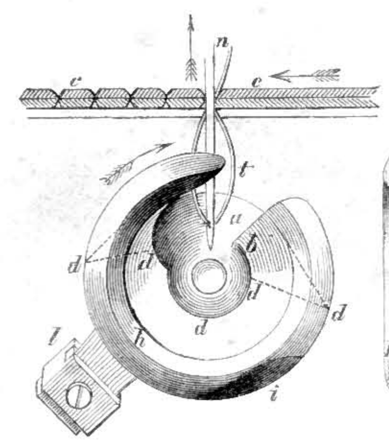

758. THE SINGLE THREAD LOOP, OR CHAIN STITCH.

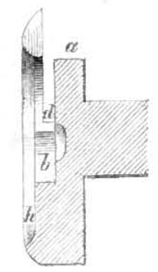

761. THE LOCK STITCH MACHINE.

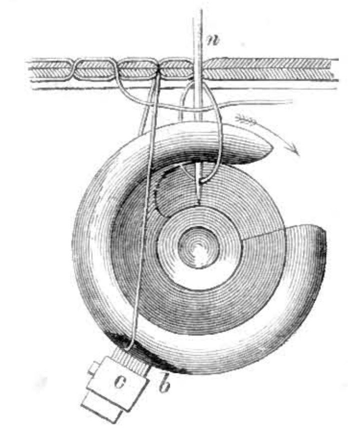

759. THE DOUBLE THREAD CHAIN STITCH.

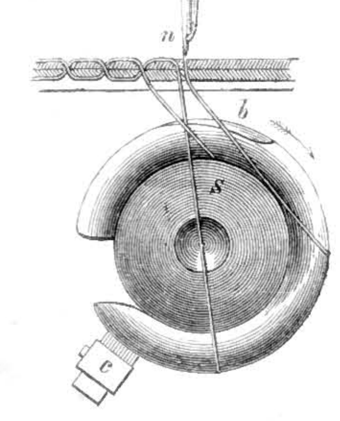

760. THE LOCK STITCH.

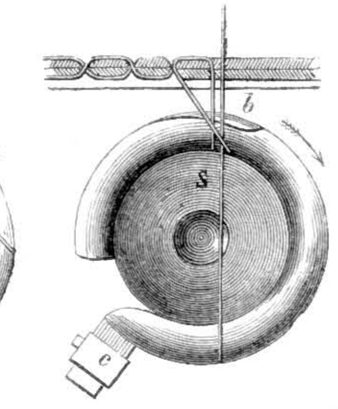

762. HOOK, SIDE VIEW.

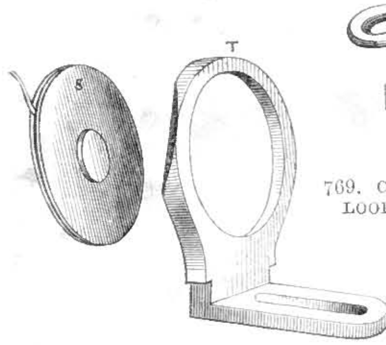

763. HOOK, FRONT VIEW.


764. HOOK, SIDE SECTION.

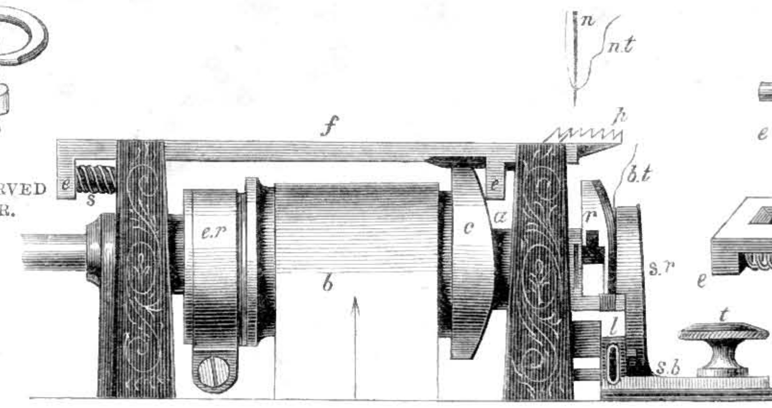

765. ROTATING HOOK, ENTERING THE LOOP.


766. HOOK IN ANOTHER POSITION.


767. HOOK AND THREAD IN ANOTHER POSITION.

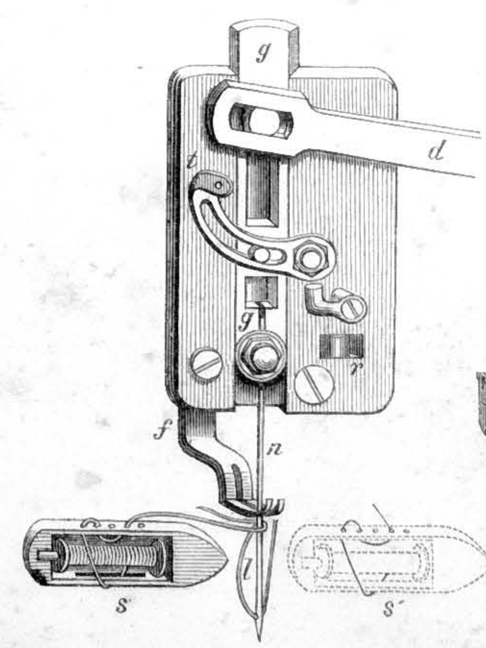

768. BOBBIN AND HOLDER.

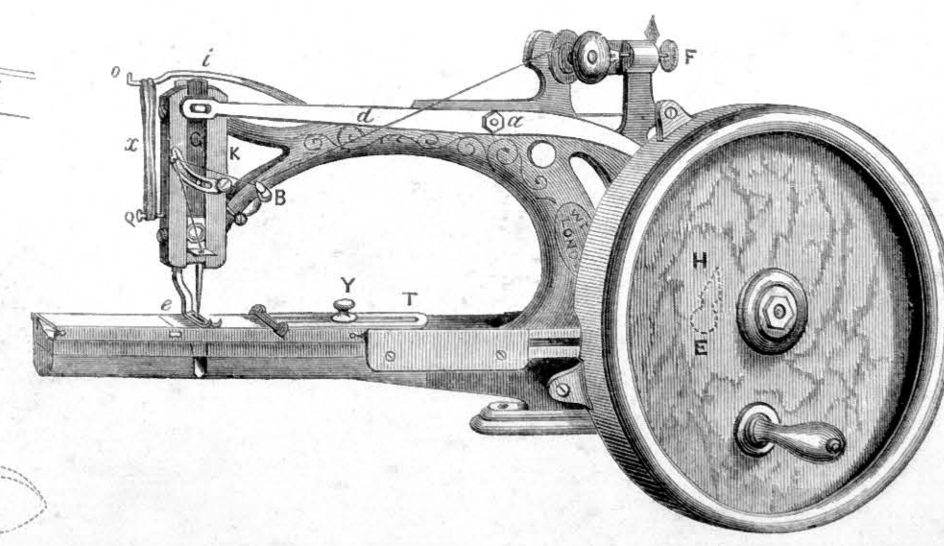

769. CURVED LOOPER.

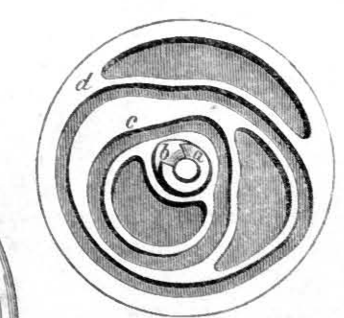

770. FEED MOTION, ETC.

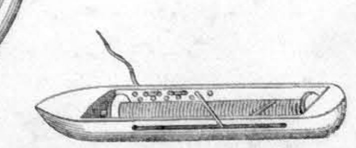

771. FEED BAR.


772. FEED BAR AND SPRING.


773. NEEDLE, SHUTTLE, AND FEED.


774. HOWE'S SEWING MACHINE, IMPROVED BY THOMAS.


775. CAM.


776. SHUTTLE AND THREAD.

as much from the upper thread as is consumed in forming one stitch.

The feed-motion will be understood by referring to figs. 770, 771, 772. In fig. 770 the cam wheel *c* has a thick and a thin part. As this wheel rotates, and its thick part comes in contact with the projecting ear *e* (also shown at *e′* fig. 772, and *e″* fig. 771), it presses forwards the feed-bar *f* (fig. 770), which by the serrations *p p p*, seen in all three figures, moves the cloth forwards through the space of a stitch. While the thick part of the cam-wheel *c* is acting on the ear *e*, the spiral spring *s* is compressed; but when the thin part of the wheel *c* comes round, the spiral spring opens and the feed-bar is moved to the left, and by these alternate motions the cloth is moved forwards. There are arrangements for raising the presser-plate, fig. 761, when the feed-bar *f*, fig. 770, moves forward. There are also adjustments for regulating the stitch, whether long or short. The feed-apparatus is of course mechanically performed, as already described, although from the position of the hands in fig. 761, it might be supposed that the attendant was moving the cloth under the needle, whereas she is only keeping it in a straight line. In fig. 770, *n* is the needle, *n t* the needle-thread, *b t* the bobbin-thread, *s r* and *s b* being the bobbin-holder, shown separately in fig. 768, secured by the thumb-screw *t*, while *r* is a portion of the rotating hook, seen sideways, as in fig. 764. In this last figure the hook is shown in three thicknesses, *h* being the front groove which receives the bobbin, the axis fitting into *b*, while *a* is the back of the hook corresponding with *a*, fig. 770. In fig. 763 the needle is in the act of rising, as indicated by the rising arrow, while the motion of the cloth *c c*, is to the left, in the direction of the horizontal arrow: the direction of the hook is indicated by the curved arrow.

In the Grover and Baker sewing-machine the thread is supplied from ordinary reels or bobbins. Below the cloth is a curved looper, fig. 769, with an eye at the heel where the bend begins, and a second eye near the point, the two eyes being connected by a groove for receiving the thread, which proceeds through the eye at the heel, and then through the eye at the point. The top needle, in descending, leaves a loop in the cloth, while the curved looper partially revolves backwards, leaving a loop of the under thread round the needle. Before the needle leaves the cloth, the point of the looper returns and passes through the loop of the needle-thread, which loop has in the meantime been opened to receive it by a partial rise of the needle. The needle then leaves the cloth, which is sent forward one stitch, and the looper remains stationary, presenting an open loop of the under thread ready for the next descent of the needle.

In conclusion, we may remark that an inspection of the various parts of the sewing-machine, which is now so common an article in household furniture, will convey a better idea of the mechanism and mode of action than the most elaborate printed description.

R. CLAY, SON, AND TAYLOR, PRINTERS, LONDON.