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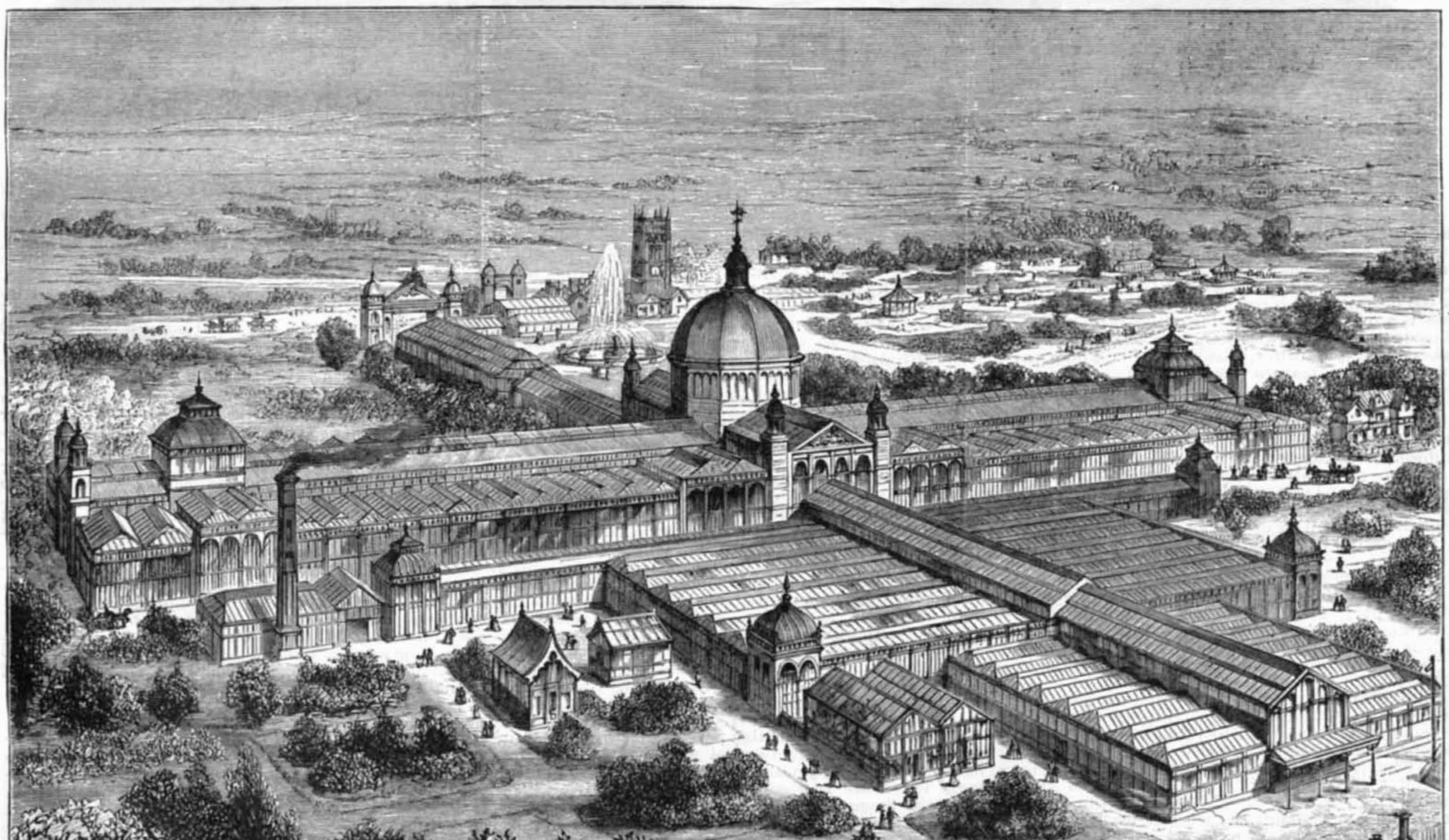
THE MANCHESTER ROYAL JUBILEE EXHIBITION—THE CENTRAL DOME.



THE MANCHESTER ROYAL JUBILEE EXHIBITION—GENERAL VIEW.

THE MANCHESTER JUBILEE EXHIBITION.

On May 3 last this exhibition was opened by their Royal Highnesses the Prince and Princess of Wales, under favorable auspices.

The Engineer, from which we take the following particulars, says: In many respects the exhibition is superior, not only in extent, but in variety, to anything that has been seen in England for several years. All the conditions are favorable to its success, for it possesses those elements of attraction which have been found so popular in London, inasmuch as it closely adjoins the botanic gardens, and as these will be thrown open to the visitors, it will be easy to provide open air attractions of no common order of merit.

The contents of the great machinery gallery fully maintain not only the reputation of Manchester, but of England. Never, since 1862, has anything like the display of textile machinery been seen within our shores.

The main building of the exhibition claims the special attention of all who are interested in iron structures. It is a remarkable example of the adaptation of means to an end.

The architects of the building are Messrs. Maxwell & Tuke.

The principal building consists of a nave or main avenue, 1,000 ft long, crossed at the middle point by transepts, surmounted by a graceful dome, which is finished above by a well proportioned lantern. Near to the ends of the nave are situated two pavilions, which rise to a considerable height above the nave roof, making with the dome a pleasing sky line, not usually found in exhibition buildings. The interior of the building when viewed from one end presents a very satisfactory vista. The nave has a total width of 100 ft., but as the sides are partitioned off to form rows for the display of furniture and other matters, the visible width of the main avenue is only 60 ft. The dome is 90 ft. in diameter, and is supported, as, indeed, is most of the roof covering, by slender clustered iron columns. The approach avenue from the royal entrance in Old Trafford road forms a most imposing corridor. It is 600 ft. long, and is covered in for its entire extent. There is a broad causeway down the center, and on each side there is a wide margin planted with exotic ferns, palms, and other foliage plants, which, as a whole, presents a feature that for luxuriance of vegetation is almost unique. This covered road is lighted after dark by electric arc lights, with excellent effect. Both north and south of the main building there is a vast covered area of ground, where the aim has been to afford protection for machinery and other exhibits, rather than to satisfy the eye by architectural effect. A special area of large extent has been devoted on the north side of the nave to the Irish section, which is well filled with exhibits of various kinds, some of which will be referred to in a future notice, but almost all of such a character as to show great excellence of workmanship and design. The large annex on the south side of the main building is almost wholly occupied by machinery at rest and in motion. This area is separated from the main building by Talbot road, across which is carried a foot bridge of 70 ft. span, which is used by all visitors arriving by rail at the exhibition station. In addition to the botanic gardens, there is a considerable area available for open air recreation. This ground is situated for the most part near Talbot road, and it contains detached buildings, notably a creamery, conservatories, billiard room and smoking room. The proximity of the botanic gardens, as a matter of course, suggested the provision of all the accessories which made the fisheries and the other recent exhibitions at South Kensington so enjoyable as a summer resort. The grounds have been rearranged to a great extent. A wide promenade has been formed, with a band stand at each end, and, as we have said, a magnificent fountain has been provided for display with electric light.

The roofs of the exhibition building contain several features of a novel kind. The architects have shown considerable ingenuity in using those forms and sections of iron that are commonly found in the market; by doing so the delay consequent upon the adoption of special designs has been avoided, for with the exception of some small castings of a special form, every portion of the roof could be procured in any desired quantity. The adoption of the ordinary forms of iron has, of course, been attended with economy in two respects. The material was doubtless cheaper at first cost, and if the building is to be taken down when its present purpose is served, the greater part of the material will be available for the purposes for which it was originally made.

The whole of the columns are built up of flanged pipes of 4 in. interior diameter, having a thickness of ½ in. and flanges of ¾ in. faced. They are placed in groups of two, three, and four, and have a very light and elegant effect. Between the flanges are fixed cast iron zones, which are beaded round the edge, and as they project a little beyond the outer edge of the flange, they almost entirely conceal the fact that so utilitarian a material as a steam pipe has been employed. These zones have a further use in some situations, as they are then cast with a lug, to which is attached any tie or bracing that is required. Ordinary angle and T iron is largely used, and it will be seen by the drawings that hardly any smiths' work has been necessary. The labor has consisted almost entirely of shearing, punching, and riveting. The arrangement of the purlins is both simple and sound in construction. They are for the most part made of wrought iron water pipes screwed in the usual way at each end; these are passed through a purlin coupling of cast iron, and are fixed in position by nuts, which are tapped to fit the screw of the water pipe.

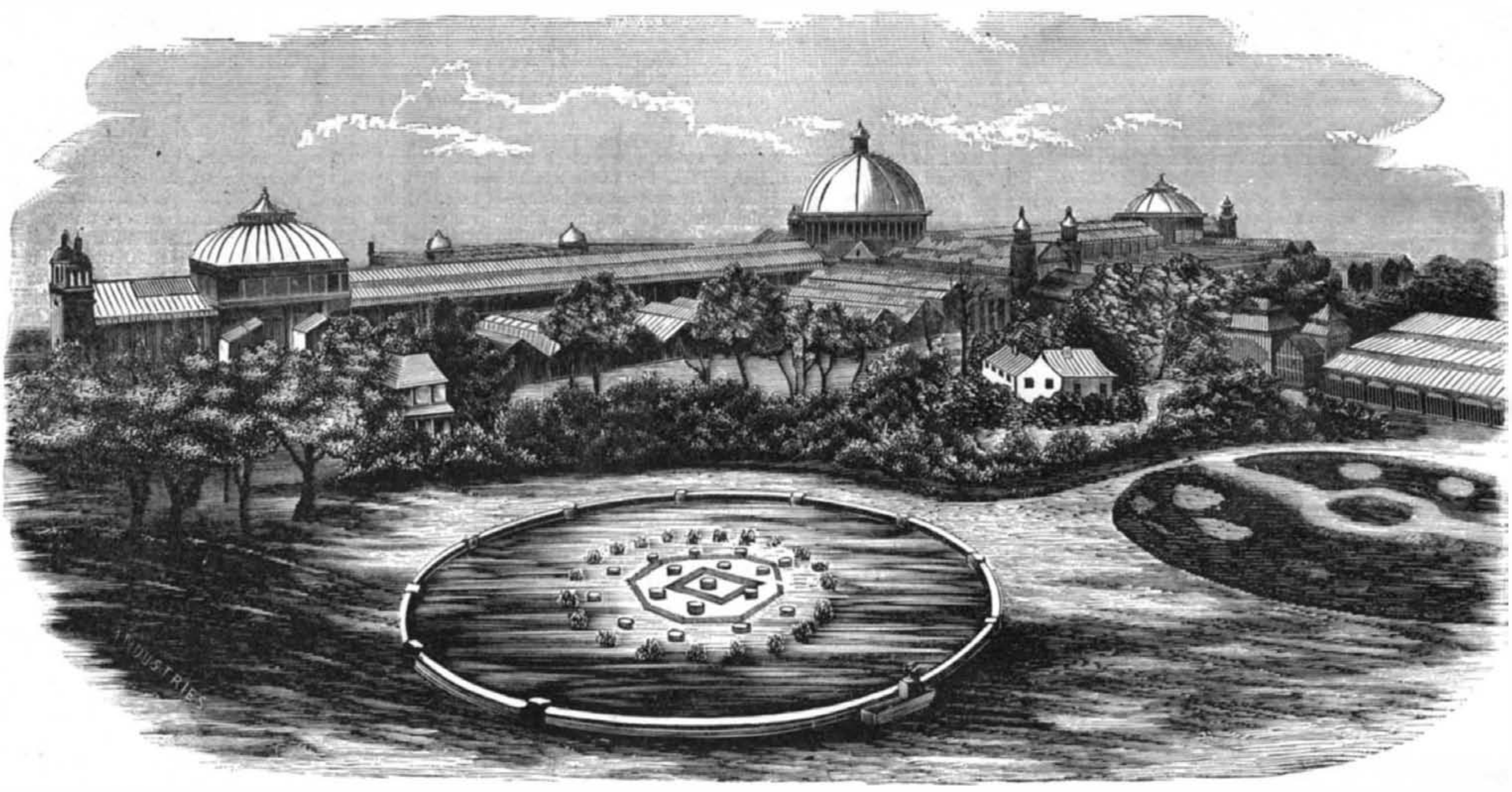
Most of the tie rods also are made of small iron water pipes, and these are attached at the ends in a simple but effective way. A piece of flat bar iron is punched with a hole in the center and a hole at each end. The bar is then bent twice at right angles, bringing the ends into proximity, so that any number of flat bars can be gripped and a bolt passed through the whole thickness. The end of the tubular tie rod is then passed through the center hole in the strap, and a nut is screwed on the end of the pipe, by which the whole can be drawn tightly together. It will be seen from the drawings that the suspending rods are also made of drawn tubes, and are attached to the tie rods by ordinary T pieces or junctions. The clustered columns are secured to the brick foundation by being bolted down to a cast iron bed plate of 1¼ in. thick. The heads of the bolts are countersunk so as to insure a uniform bearing on the brickwork, and the bed plates are secured by holding-down bolts, which are built into the brickwork.

In the roofs of the low main buildings, not only are all the members which are in tension made of drawn pipes, but the rafters and purlins are of the same class of material. The struts are of angle iron, and are attached to the purlin couplings by rivets. The shoes of the principals, and what answers for a ridge piece, are made of flat bar iron punched and formed to a suitable shape to receive the ends of the pipes which are attached with nuts, as above described, for the tie rods. The dome, which is twelve sided in plan, is of graceful form, and is very light in construction. Each rib is made up of two T irons, which are tied together by ordinary diagonal bracing of angle iron 2 in. × 2 in. × ⅜, each having a single rivet at each end. No pipes have been employed in this part of the structure, but the necessary ties are of steel wire rope, which is so light as to be hardly visible from the floor of the building. There are two complete sets of tie wires which cross the dome horizontally, but diagonally, as shown on the plan of the lantern, touching each other as they pass.

The buildings are, with very few exceptions, covered with corrugated iron, and no other material is used with it, except in the music room, at the eastern end of the building, where the inside of both roof and walls is lined with thin boarding, which, for obvious reasons, is more suitable than galvanized iron and ordinary brickwork.

The exhibition buildings are situated at some distance from the center of the city, but there are ample facilities provided for reaching it by both road and rail. The principal or, as it is called, the royal entrance is in Chester road, a few yards from the gates of the botanic gardens. The exhibition is divided into two sections by Chester road, a thoroughfare 70 ft. wide; on the north side is the main building, on the south the great machinery hall, 510 ft. long and 210 ft. wide. This will be devoted to machinery in motion; opening off it, still to the south, is an annex 180 ft. square for machinery at rest. The entire building is, as we have already stated, lighted by electricity. The contract for the whole of the arc lighting has been placed with the Anglo-American Brush Electric Light Corporation; the total number of lamps employed is 546, exclusive of those required for the private use of exhibitors. All the lamps are of the Brush standard pattern, working with a current of 10 amperes, and are maintained by twenty-six dynamos, inclusive of spare machines; the engines employed to drive the dynamos are by Messrs. Robey, Hornsby, Davey Paxman, Ruston Proctor, and Yates, and are arranged to suit the requirements of the several circuits as nearly as possible.

Our front page sketches are from the *Illustrated London News*, and the north view from *Industries*.



THE MANCHESTER ROYAL JUBILEE EXHIBITION—VIEW FROM THE NORTH.

THE AMERICAN EXHIBITION IN LONDON.

The American Exhibition, between Earl's Court, West Kensington, and West Brompton, of which we have given some account (see engraving, Supplement, No. 594), is an undertaking of as much novelty as of imposing magnitude. It is the first exhibition devoted exclusively to the arts, inventions, manufactures, products, and resources of one nation held on the soil of another country. It covers a space of twenty-four acres, in the heart of residential London. The exhibition may be divided into three great departments. There is, first, the main building, in itself a novelty in architecture, around which, together with the art gallery adjoining, centers the serious interest of the exhibition. Secondly, there are Buffalo Bill's "Wild West" grounds, which have a historical interest, as a pictorial representation of a phase of life now almost, if not not quite, vanished, and as showing the methods by which the enterprising people of the United States have reclaimed to civilization that vast space of the North American continent which twenty or thirty years ago was designated upon the maps as unexplored. Thirdly, there are the horticultural and pleasure gardens, nearly twelve acres in extent, showing the flora of North America as completely as climatic conditions will allow, and furnishing outdoor amusement for the vast numbers of people who are confined to London in the summer season, and must seek their recreation within the metropolitan boundaries.

It is always a matter of interest to know something of the appearance, history, and characteristics of the men who initiate and carry to completion gigantic enterprises. In this case, the first of these persons is Mr. John Robinson Whitley, of London, the director-general. The idea of holding such an exhibition in London impressed him, from the English standpoint, as a brilliant one, and he entered upon the colossal work, in face of what seemed almost insurmountable obstacles, to carry it through to a successful completion, with all the energy, enthusiasm, and untiring industry which are characteristic of the man. He brought to the work a peculiar fitness, acquired by previous experience in the great international exhibitions which had preceded this, and in which he had participated as an exhibitor, especially at Paris, in 1878, where he represented some fifty firms. This experience, together with his business as a merchant and manufacturer, and his wide knowledge acquired from travel all over the world, made him fully alive to the fact that in America there was enough, of which nothing was known to the European world, to make an interesting, popular, and valuable exhibition. He has from the beginning taken entire charge of the work in Eng-

land, and, in addition, has spent twelve months in visiting every part of the United States in the interests of the great work he has undertaken, and which has now become, from what seemed almost a chimerical idea, a substantial reality.

Colonel W. F. Cody is known to the world as "Buffalo Bill," a title acquired by having shot 4,280 buffaloes in one year. His life, from boyhood, has been spent on the Indian frontier, and he has passed through every phase of border life, always with credit to himself, as hunter, trapper, guide, and scout. He has endured dangers and difficulties the recitation of which would fill many volumes, and in every pursuit he has achieved the distinction of being the bravest, the most thorough, the most active, the most chivalrous and most daring man whom that phase of American civilization has ever produced. He has been Chief of Scouts of the United States Army, member of the Legislature for the State of Nebraska, and is now colonel and *aide-de-camp* on the staff of the governor of that State.

Captain Burnet Landreth, of Philadelphia, is a member of the great seed firm of D. Landreth & Sons. He served with distinction during the war of the rebellion, and his experience as a soldier developed in him great abilities as an executive officer. He was Chief of the Bureau of Agriculture at the Centennial Exhibition of 1876, and gave to that department remarkable prominence and importance.—*Illustrated London News.*

NUTRITIVE VALUE OF FUNGI.

IT is generally thought that edible fungi are very nutritious, and, according to popular prejudice, such food has even a nutritive value equal to that of meat. According to *L'Engrais*, Mr. C. T. Morner, a German chemist, has thrown light upon the question by submitting various edible fungi to artificial digestion. The total nitrogen that these fungi contain varies between 2 and 3·64 per cent. in the dry material. Forty-one per cent. of the total nitrogen is useful in alimentation; all the rest belongs to non-assimilable bodies. Nothwithstanding these relatively high figures, fungi constitute a very mediocre food, since the figures relate to dry material, and fungi contain enormous quantities of water. Mr. Morner's conclusions are as follows:

As a substitute for one egg it would require of—

Common mushroom	10 ounces.
Lactarius deliciosus	1½ lb.
Chanterelle	2¾ "
Polyporus ovinus	4½ "

As a substitute for a pound of beef it would require of—

Mushroom	9 lb.
Lactarius deliciosus	24 "
Chanterelle	41 "
Morel	15 "
Polyporus ovinus	67 "

If a person desired to live exclusively upon fungi, he would have to consume per day, in order to find in them the requisite four ounces of albuminoids:

Mushroom	12½ lb.
Boletus	21¾ "
Lactarius deliciosus	32¼ "
Chanterelle	57¾ "
Polyporus ovinus	91½ "

ALUMINUM.

WE have recently had the opportunity of seeing commercially pure metallic aluminum produced direct from its ore by a process invented and carried out by Dr. Kleiner, of Zurich. The entire operation only occupies from two to three hours, and is effected by the simplest apparatus. A steam engine, a dynamo, and a hearth or melting vessel are all that are absolutely necessary, and by these appliances the aluminum is divorced from the elements with which it is combined in the ore, and is produced in lumps, which vary in size from a marrow-fat pea to a small potato. The agent which effects the reaction is the electric current, but it plays an entirely different part from that which it takes in the Cowles aluminum furnace. In that the current is merely a source of heat, and serves to raise the aluminum ore (corundum), together with the copper and the carbon, by which it is surrounded, to such a temperature that the oxygen in the ore combines with the carbon, and the aluminum alloys itself with the copper.

In the Kleiner process it is the chemical power of the current which is principally brought into play, the metal being extracted by electrolysis at a low temperature. At the same time there is sufficient heat developed to fuse the ore, and thus bring it into a fluid condition, which is an essential condition of a material before it can be electrolyzed. As the substance employed melts at a low heat, it rapidly attains the fluid state and becomes a conductor, and after this is arrived at there is little or no further rise of temperature, as the comparatively large area of the bath offers but small resistance to the passage of the current, and hence after the preliminary operation is complete the action becomes mainly chemical.

The ore employed is cryolite, a double fluoride of sodium and aluminum. This is ground to a fine powder, and under the action of the current has its aluminum removed, leaving a double fluoride of sodium, which is soluble in water. After the process has been carried as far as is commercially economical, the slag is allowed to cool, and is then broken up and washed. The metal comes out in lumps, the soda salt is dissolved, and can be saved for conversion into caustic soda, while the unreduced ore, which is insoluble, is dried and returned to the bath. It will be seen from this that the two elements of the process are the ore and the power required to drive the dynamo. As aluminum enters into very firm union with other bodies, it requires the expenditure of a large amount of energy to break up the connection, the theoretical result attained by an amount of electric energy represented by one horse power per hour being 3½ grammes ($\frac{1}{100}$ lb.). Of course the full efficiency cannot be obtained in practice, but in an experiment made in London, by Dr. John Hopkinson, F.R.S., it appears that 3 grammes of metal per horse power are already attainable when working on a very moderate scale. In other words, a dynamo machine giving 100 electric horse power, and working twenty hours per day, would produce 80 lb. of pure aluminum per week of six days.

The hearths or crucibles in which the operation is carried out are very simple. According to one arrangement, an ordinary plumbago crucible has a carbon electrode, formed of a group of rods, inserted through the bottom (negative), and a second electrode (positive), fixed to a bracket above, dipping into it. Another method, which is preferred, is to use a vessel or cavity formed of bauxite, pressed hydraulically into a box or case.

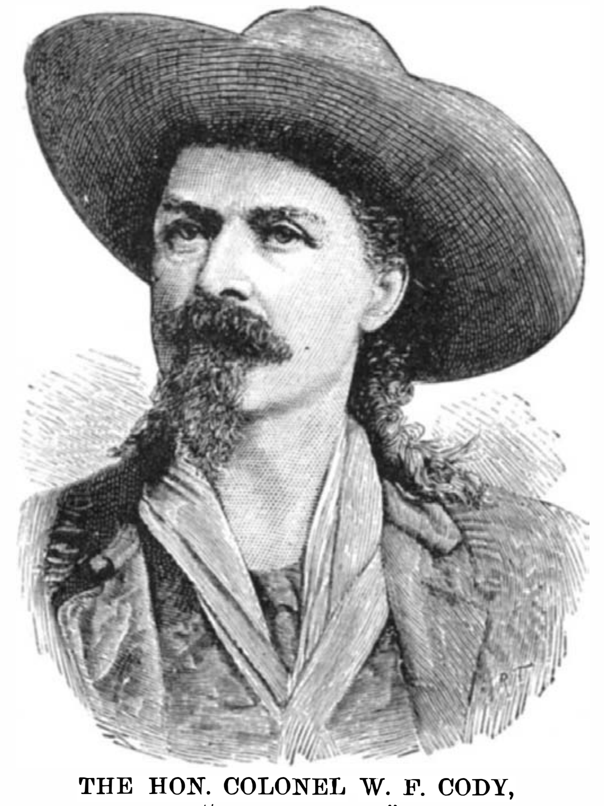
In either case the heat is so low, and is so entirely confined to the interior of the bath, that there is no injurious action on the walls. At the commencement of the operation the ground and dried cryolite is placed in the vessel until the lower electrode—the cathode—is covered, and then the center rod of the upper electrode is lowered until an arc is established, the current having about 80 to 100 volts and 60 to 80 amperes. A very short time suffices to effect the fusion of the cryolite in the immediate vicinity of the arc, and fresh powder is added until there is a glowing fluid mass in the center of the bath. This makes a path for the current, which no longer forms an arc, and as the heat extends, other rods of the upper electrode are gradually brought down, until the greater part of the contents of the bath are exposed to the current. At the same time the electromotive force of the current is reduced to 50 volts. A smooth and tranquil fusion, at the lowest possible temperature, is maintained from two to three hours, and then the process is stopped and the current switched on to another vessel.

An important and valuable improvement on the above has, we learn, just been patented by Dr. Kleiner. It was found that the consumption of the carbon rods used as anodes formed an expensive item of cost in the process; and having observed that the ends of these rods submerged in the molten bath of cryolite remained almost intact throughout the operation, while that portion immediately above the surface, and for about 2 in. to 3 in. upward, was more or less eaten away to the core, it was decided to adopt a new system of applying the positive carbons to the bath. This system consists in completely submerging hollow cylinders of pure carbon in the melted cryolite, and connecting them with the positive current by means of projecting ears through each side of the vessel; while the negative carbon is raised up through the bottom of the vessel until its apex is on a level with the upper part of the hollow carbon cylinder. Being thus fixed in position, the powdered cryolite is fed in as in the previous system, and the first fusion is achieved by forming an arc between the negative carbon and one long carbon rod suspended from the top, used only for this purpose, and which can be moved in any direction by the hand, so that as the cryolite around the two poles is melted, the positive rod is slowly moved across the vessel toward the hollow carbon cylinders forming the sides, until the current freely flows through the melted cryolite between these and the negative carbon in the center. This requires about ten minutes, and once attained, the carbon rod is withdrawn, and the electrolytic process continues its even course to the end—the bath flowing smoothly—while the hollow carbon cylinders, scarcely, if at all, attacked, will serve over and over again.

Such is the process now adopted, and it will be readily seen that not only is it simple, but also that its cost can be readily calculated. Cryolite can be obtained practically pure from Greenland in any quantities at from 18*l.* to 20*l.* a ton at the outside, but an artificial cryolite can be made at about half this cost, and no doubt will be as soon as there is a demand sufficient to warrant its manufacture on a large scale. Its exact composition is $Al_2Fl_6 6NaFl$, the proportions of the various elements being aluminum, 12·85 per cent.; sodium, 32·85 per cent.; and fluorine, 54·30 per cent. The production of electricity in large currents is no longer a matter of experiment, and its cost can be calculated exactly, being merely a matter of horse power. In order to reduce this expense, water rights over half the River Rhine at Shaffhausen, where the Rhine falls are situated, had been acquired by those interested in Dr. Kleiner's process, together with a site occupying six acres of freehold ground, but unfortunately the government of the cantons of Shaffhausen has declined to allow the falls to be used to this extent, on the grounds that the hotel keepers in the neighborhood would be prejudiced by the falling off in tourists and visitors who annually flock there in thousands to admire our European Niagara. It is calculated that the power at this spot is equal to 15,000 horse power, and that it would suffice to produce 600,000 lb. of aluminium per annum at an extremely cheap rate. Even if only a part of the power was employed in the first instance, the metal could be put on the market at half the present rate, and yet yield a very high profit to the manufacturers. However, this is an aspect of the matter which does not concern us at present. Any one who is interested in it can form for himself a pretty correct estimate of the cost of aluminum by this process, whether the power be obtained from a waterfall or from steam engines situated in a district of cheap fuel.*

It is not easy to point to any actual demand for pure aluminum on a large scale, but its qualities are such that it may be confidently predicted that the supply would create the demand. In the form of an iron alloy it is already used in the production of "mitis" castings, and all who have had the opportunity of examining these productions will understand what extensive openings will be found for them in the future. Textile machinery alone could absorb enormous quantities of them, while if it be proved true, as stated, that the addition of aluminum to steel will insure sound castings, another wide outlet for the metal will be found. For military and naval appliances, where lightness is often of the greatest consequence, the use of aluminum bronze is assured as soon as the price is reduced, while in the arts an alloy with the appearance of gold, the strength of steel, and the ductility of charcoal iron

MR. JOHN ROBINSON WHITLEY,
DIRECTOR-GENERAL.



THE HON. COLONEL W. F. CODY,
"BUFFALO BILL."

CAPT. BURNET LANDRETH, OF PHILADELPHIA,
DIRECTOR IN THE UNITED STATES.

THE AMERICAN EXHIBITION IN LONDON.

* Indeed, since the Rhine falls have been refused to those interested in the patents, we are informed they have decided to hire a large mill either in Wolverhampton, Birmingham, or Lancashire, with a minimum of 500 horse power, in order to test the process on a small commercial scale for a year, and if successful increase the power to several thousands. The output of pure metal (aluminum) from these preliminary works will not be less than 200 lb. per week.

must find a thousand purposes for which it will carry its own recommendation. Dr. Kleiner's process was first noticed in June, 1886, and brought into its present practical prominence by Major Ricarde-Seaver, F.R.S.E., who, during some years, has given special scientific attention to the production of aluminum. We are indebted to his courtesy for the opportunity of visiting the works in Farringdon road, and thus giving the first public technical description of this interesting invention. The dynamos used are the Edison-Hopkinson, made by Messrs. Mather & Platt, Manchester, and for electrolytic purposes seem all that can be desired, although not specially built with that object.—*Engineering.*

A PLANT THAT DESTROYS THE TASTE OF SUGAR.

AN EXAMINATION OF THE LEAVES OF GYMNEMA SYLVESTRE.*

GYMNEMA SYLVESTRE (R. Br.) is an asclepiadaceous plant growing in the Deccan peninsula, from Concan to Travancore; it is also met with in Assam, and on the Coromandel coast, and is distributed in the continent of Africa. It is a stout woody climber, with long, slender branches.

The leaves are opposite, entire, from 1½ to 3 inches long, and from 1 to 2 inches broad, elliptic or obovate, acute or cuspidate, rarely cordate at the base, membraneous, thinly pubescent on both sides, the upper surface of a darker green than the lower. *Gymnema sylvestre* is mentioned in the non-official list in the Pharmacopœia of India (1868), and in Dr. Dymock's "Materia Medica of Western India." The powdered root has for a long time been known among the Hindus as a remedy for snake bites. In such cases it is applied locally to the part affected, and also taken internally in the form of a decoction. But the most curious circumstance connected with this plant was first noticed by Mr. Edgeworth, who discovered that by chewing some of the leaves it destroyed the power of the tongue to appreciate the taste of sugar. He found that powdered sugar, taken immediately after masticating some of the leaves, tasted like so much sand in his mouth, and this effect lasted for twenty-four hours. Dr. Dymock, reviewing this property, said he was unable entirely to confirm this statement. His experience was that sugar taken into the mouth after chewing the fresh plant had a saltish taste, but was still easily recognizable.

Some authentic leaves were procured by Mr. Lawson from Guindy Park, Madras, who placed them at my disposal for chemical examination. They had a bitterish astringent and slightly acid taste. After chewing one or two leaves, it was proved undoubtedly that sugar had no taste immediately afterward; the saltish taste experienced by others was due to an insufficiency of the leaf being used. Sugar in combination with other compounds in dietetic articles is plainly destroyed as to its taste after using these leaves. In gingerbread, for instance, the pungency of the ginger is alone detected, the rest is tasteless meal; in a sweet orange the taste of the sugar is so suppressed, and that of the citric acid consequently developed, that in eating it resembles a lime in sourness.

Among the several kinds of foods, drugs, and beverages which affect the palate, gymnema does not pretend to render them all tasteless; it does not affect pungent and saline things, astringents, and acids. It is limited to apparently two diverse substances, sweets and bitters. It has been noted that sugar taken after the leaf tastes like sand, so I have found that sulphate of quinine taken after a good dose of the leaf tastes like so much chalk. I am not going to propose its use in the administration of nauseous drugs, until the medical properties of the gymnema have been more studied, otherwise the quantity of the vehicle taken may prove to counteract the effect of the medicines. The experience of several friends as well as my own is that the effect does not last for twenty-four hours as stated, but for only one or two hours; after that time the tongue resumes its appreciation of all that is sweet or bitter.

The powdered leaves were submitted to the action of various solvents, and by this means it was ascertained that the peculiar property of gymnema leaves was dissolved out by alcohol, and, as it occurred in the aqueous extract of the residue, it was therefore soluble in water. As benzene and ether took from the leaves certain principles of the same appearance and weight, it was conceived that nothing would be gained by using both solvents; the preliminary extraction was therefore made with ether rectified from water and spirit. The ether extract consisted of chlorophyl and two resins separated by their solubility in alcohol. The resin insoluble in spirit formed the larger portion; it was soluble in chloroform, bisulphide of carbon, and benzene. It was elastic and tenacious, decomposed by warming with nitric acid, the product being precipitated with water; only partially saponified with caustic potash. Sulphuric acid dissolved it in the cold, giving a green solution. It seemed to consist principally of a neutral resin. The resin soluble in spirit was readily saponified with soda, and gave a permanent bluish-green color with sulphuric acid; like the former resin, it was of an acrid nature, and left a tingling sensation in the throat.

The alcoholic solution of the leaves was almost entirely soluble in water; in fact, by treating the leaves separately by alcohol and water, 36·37 per cent. organic matter was extracted; by treating the drug with water alone, 36 per cent. was removed. By direct experiment it was found that in the former extract 0·47 per cent. was an acrid resin similar to those found in the ether extract. The aqueous solution of the substances soluble in alcohol had a decidedly acid reaction; it gave no coloration with ferric chloride, showing absence of tannin. It was deepened in color with alkalies, but gave a bulky precipitate with sulphuric, nitric, hydrochloric, and acetic acids. It reduced Fehling's solution on boiling, and gave a cloudiness with Nessler, a precipitate with lead acetate, but none with tannin or picricacid. The precipitate caused by sulphuric acid was collected on a filter and washed till it ceased to give a cloudiness with barium chloride. It yielded a greenish powder, insoluble in water, but soluble in alcohol, ether, benzene, and chloroform. With potash, soda, and ammonia it afforded fine red solutions with orange colored froth, but they were both precipitated on the addition of the mineral acids. It dissolved in concentrated sulphuric and nitric acids with intense red color, but in both mixtures it was destroyed and precipitated by water. It fused at about 60° C. into a blackish brittle mass. Heated in a test tube it gave off fumes of creosote, but no crystals were obtained in a subliming apparatus. Gently ignited, it burned with a bright flame, leaving no ash. It was thrown down as a bulky gray mass by acetate of lead; the lead salt decomposed by sulphureted hydrogen in water left the substance in the reddish evaporated filtrate from the lead sulphide.

The body just described has the characteristics of an organic acid related in some particulars to chrysophanic acid, but having some distinctly peculiar reactions, and possessing the anti-saccharine property ascribed to the leaves. I propose to call it *gymnemic acid.*

Gymnemic acid forms more than 6 per cent. of the constituents of gymnema leaves, in combination with a base which has not been isolated. Another organic acid was present in the lead acetate precipitate, which was identified as tartaric acid. The filtrate from the insoluble lead compounds was treated with sulphureted hydrogen gas, and the clear liquor after evaporation was examined for sugar. Glucose was detected in some quantity by its immediate and abundant reduction of Fehling's solution; the sugar examined in a polariscope had a left-handed rotation.

Chloroform agitated with an alkaline solution of the leaf left a crystalline residue of a brownish color; it had a bitter taste, and acted as a sialagogue. With the ordinary alkaloidal reagents it afforded colored precipitates, but was a neutral principle. Its further examination, together with that of gymnemic acid, is reserved for further investigation.

The leaves after being exhausted with ether and then alcohol were treated with water. The gum was detected and estimated in the usual manner. A carbohydrate, optically inactive, and, after boiling with acid, reducing Fehling's solution, was found in this extract.

Diluted soda removed a brownish liquid which consisted of albuminous matters only partially soluble in alcoholic and acetic acid. These were not weighed, but calculated by difference.

A solution of 1 per cent. hydrochloric acid was employed to remove the oxalate of calcium. A microscopical examination of the powdered leaves showed a fair sprinkling of the conglomerate crystals or raphides so well known to exist in rhubarb. The dilution of the acid menstruum rendered this process very tedious, so a stronger acid was used and the marc washed with it until ammonia produced no cloudiness. The collected liquors were allowed to deposit, the sediment was then collected on a filter, dried, and weighed; then incinerated and weighed again. The calcium carbonate was calculated into oxalate, and the difference between this and the first weighing was reckoned as pararabin. No oxalic acid was found in a free state.

The ash of *Gymnema sylvestre* is very high, a fact in accordance with the amount of lime salts it contains. Gentle ignition of the air-dried leaves left as much as 11·65 per cent., and about one-half of this was calcium carbonate. One hundred parts contained:

15·41 soluble in water.
78·71 soluble in acid.
5·88 sand and siliceous residue.

The cellulose was estimated by steeping the leaves in sulphuric acid of specific gravity 1·50 for 30 hours, washing, drying, burning, and deducting the ash; this result did not differ materially from the weight of the totally exhausted powder treated with chlorine water.

The following is a tabulated analysis of the powdered and sun-dried leaves:

Ether extract (chlorophyl and resins)	5·51
Alcoholic extract (gymnemic acid, tartaric acid, glucose, neutral bitter principle, resin, etc.)	19 50
Aqueous extract (gum 1·45 per cent., glucose, carbohydrate, and extractive)	16·87
Alkaline extract, by difference (albuminous and coloring matters)	8·15
Acid solution { calcium oxalate	7·64
Acid solution { pararabin	2·74
Ash (balance of)	5·69
Cellulose	27·86
Moisture	6·04
	100·00

* A paper read at a meeting of the Nilgiri Natural History Society, Ootacamund, by David Hooper, F.C.S., March 7, 1887.—*Nature.*

CELLULOSE.

By R. B. GRIFFIN and A. D. LITTLE.

CELLULOSE is to the paper maker the substance upon which his whole art depends. In its purer form, as cotton or linen fiber, or the product of the different chemical wood pulp processes, it forms the basis of all that he produces, and associated with various chemical modifications of itself it has in the shape of ground wood made possible the present enormous production of cheap printing paper. In view of the great importance thus given to the subject, it is to be regretted that the chemistry of cellulose is as yet in a very imperfect condition. Much is merely hinted at, and much more probably is wholly unknown. In view of the present state of our knowledge, therefore, the writer will only touch upon the theoretical aspects of the subject, confining himself mainly to its well known chemical relations and reactions.

The physical features of the ordinary forms of cellulose are familiar to all paper makers. It is essentially vegetable in its origin, although it is said to have been found in certain of the lower orders of animals, in degenerated human spleen and in the brain. It occurs ordinarily in the shape of plant hairs or fibers, which vary in length and somewhat in other characteristics, as they are obtained from different sources. The cotton hairs appear under the microscope as long ribbons, thickened at the edges and twisting in all directions, while the purified fibers from certain dense woods are so short as to appear to the unaided eye as scarcely more than dust.

The most striking and valuable chemical property of cellulose is its remarkable indifference to nearly all chemical reagents, treatment which would cause the metals or even glass to dissolve having scarcely any effect upon it. It has, however, a powerful attraction for certain salts in solution, and water containing them may be so filtered through a mass of cellulose as to have the dissolved salts completely removed. This attractive power is so strong in the case of vanadium compounds that cellulose will separate them from solutions containing only one part in a trillion.

Cellulose dissolves in a number of reagents, but in all cases except the one immediately to be mentioned it undergoes chemical change, so that the phenomenon is not one of simple solution. In Schweitzer's reagent, however, cellulose is readily brought into solution, and may subsequently be recovered without change of composition. This reagent is best prepared by dissolving freshly precipitated copper hydrate in strong ammonia. Under its influence cellulose, as in the shape of pure filter paper, softens, swells, and soon passes into a thick, sirupy solution from which, on the addition of acid, it is precipitated in dense flocks. A commercial process for waterproofing paper depends on the action of Schweitzer's reagent, which is allowed to remain in contact with the sheet long enough for the fibers to become superficially softened, in which condition they may be pressed into a continuous mass.

Cellulose belongs to the group of bodies known in chemistry as the carbohydrates, and which comprises in addition the sugars, dextrine, starch, etc. The relationship between these bodies is very close, and is made evident by a large number of reactions. Thus it is possible to form cellulose in the laboratory by the action of certain ferments on ordinary sugar, and it has been shown that in the case of the sugar cane the formation of cellulose is attended by a directly proportional decrease in the amount of sugar present; indeed, it is probable that, speaking generally, the formation of cellulose in living plants is due to the action of ferments on the sugar in the plant.

Strong sulphuric acid dissolves pure and thoroughly dry cellulose, and forms an almost colorless solution, which, on dilution with water and boiling, yields dextrine and glucose. Under the same conditions, starch acts similarly and gives the same products. With rather more dilute acid—one part water, four parts sulphuric acid—cellulose dissolves, and from the solution, on addition of a large amount of water, it is precipitated as *amyloid*, which dries to a horny mass, which is now attracting considerable attention in the arts. It forms the outer covering of the parchment paper now largely used for tying up the tops of bottles and preserve jars, and which is made by dipping ordinary unsized paper for a few seconds in sulphuric acid diluted with a quarter or more of its bulk of water. The paper is then washed with water containing ammonia, then with pure water, and will be found to have acquired a remarkable toughness and many of the properties of animal parchment. Concentrated solutions of zinc chloride effect similar transformations into amyloid and parchment paper.

The action of chlorine upon cellulose is of the utmost importance to the paper maker, and has been quite carefully studied. When chlorine gas is passed into water containing cellulose in suspension, the cellulose is rapidly oxidized, and the same effect is produced on heating cellulose with a solution of a hypochlorite as bleaching powder. The extreme effect of this treatment is to convert the cellulose into oxycellu ose, a substance of very friable nature and containing more oxygen than ordinary cellulose. It is evident therefore that in bleaching cellulose care must be taken that the solution of bleaching powder is not too strong or the bleaching temperature too high. Oxycellulose can also be produced by the continued action of a comparatively small amount of bleach solution. If a mass of fiber should be saturated with the solution, then squeezed nearly dry and allowed to remain in the air for some time, it will be found that the fibers have lost their strength and become brittle through the formation of oxycellulose. The importance of thoroughly removing by washing or otherwise the last traces of chlorine from half stuff becomes self-evident in this connection. This forming of oxycellulose, however, even takes place, though only slowly, in the simple presence of light and air, and is the main cause of the deterioration of paper by age. In cases where resin size or much ground wood is used, this ageing is largely due to the action of the active oxygen or ozone in the air on the resinous and woody matter present.

Hydrocellulose is a body resembling oxycellulose in many properties and which has, with little or no occasion, attracted considerable notice in connection with the pulping of wood by the sulphite processes. Hydrocellulose, although generally retaining the form of the cellulose from which it was derived, is very brittle and easily acted upon by chemical reagents. It is formed by the long-continued action of certain dilute acids, as hydrochloric, at the boiling temperature. Many careful examinations of sulphite fiber have, however, failed to show any sign of this substance.

The action of nitric acid upon cellulose is peculiarly interesting, and has received important applications in the arts. The effect of the moderately strong acid is to form varieties of oxycellulose. As the strength of the acid is increased, however, and particularly when a mixture of nitric and sulphuric acids is employed, the cellulose is converted without change of form into compounds of nitric acid and cellulose, known as gun cotton, pyroxyline, etc. Certain of these nitrates dissolve in a mixture of alcohol and ether, the resulting solution being widely used under the name of collodion by photographers and surgeons. These nitrates explode with great violence under proper conditions, but when wet can be handled with such freedom from danger that gun cotton when manufactured on the large scale is commonly freed from adhering acids by washing in an ordinary rag engine.

Unless carefully made and thoroughly washed, there is great liability that gun cotton will explode spontaneously, and to show how near one may come to living on a volcano without realizing the fact, it is worth mentioning that in the early part of the century a process was employed commercially in France for the manufacture of wood pulp, which consisted in dissolving the incrusting matter of the fiber by treating the chips with strong nitric acid. The process was conducted in great stoneware jars, and yielded quite good pulp for the times, but was finally abandoned on account of cost and difficulty of working. In such a process there was, of course, though unknown at the time, great danger of forming explosive nitrates of cellulose.

By special treatment and incorporation with camphor

gun cotton is converted into celluloid and zylonite, both of which are now widely used as substitutes for ivory, tortoise shell, coral, etc.

Caustic soda and caustic potash, when in dilute solution, do not readily attack cellulose, even on boiling under considerable pressure. Cotton wool heated to 160° C., with a concentrated solution of caustic potash, dissolves completely, and under the conditions observed in the manufacture of wood pulp by the soda process a portion of the cellulose is dissolved, together with the incrusting matter.

The effects of heat alone upon cellulose are noteworthy. At temperatures between 100° and 160° C. cellulose is slowly decomposed, with gradual elimination of the water with which it was chemically combined. A sample of perfectly pure and dry pulp will therefore slowly continue to lose weight under prolonged heating, and this fact has doubtless given rise to many controversies regarding the dry weight of shipments of wood pulp.

Under the influence of a considerably higher degree of heat than those mentioned cellulose, if protected from the air, decomposes into a variety of acid, tarry, and gaseous products, leaving a residuum of carbon and charcoal.

Cellulose is rapidly acted upon by water at temperatures below 200° C., being converted into dark brown products, mainly insoluble. Wood chips are similarly affected at temperatures below 150° C., becoming, in the presence of water alone, badly burned and brittle.

The decay of cellulose in nature, where it generally occurs associated with other bodies, as woody tissues, is greatly hastened by the action of a ferment occurring in sewage and in fertile soils. Under this action cellulose is rapidly decomposed into carbonic acid and a marsh gas.—*Paper Trade Jour.*

DETERMINATION OF NITROGEN IN COMMERCIAL FERTILIZERS.*

By B. B. Ross and L. W. Wilkinson.

At a meeting of official agricultural chemists held in Washington, September 1 and 2, 1885, the committee on nitrogen reported that the samples sent out by the committee were so few and meager and the discrepancies so large as to make it inadvisable to recommend any method for the determination of nitrogen for use during the next season, and recommended that the entire report of the last committee be referred, without further action, to the next committee on nitrogen. The new committee, in accordance with the report referred to, sent out other samples during the present year, with specific instructions to be followed in determinations according to the Ruffle method, the one proposed by the committee for adoption by the association. Nitrogen was also determined in the same samples, for the purpose of comparison, by the soda lime and the Kjeldahl methods. As these determinations were made with great care, the results are believed to be of sufficient interest to justify their publication.

The reagents used in the Ruffle method consisted of standard solutions of sulphuric acid and caustic potash, one-fourth normal; soda lime crushed, one-half in form of powder, and one-half granular; sodium hyposulphite, commercial, fused, water-free, and powdered; finely powdered charcoal and flowers of sulphur, equal parts by weight; and cochineal solution as an indicator. The combustion tube was twenty inches in length and one-half inch in diameter.

The samples used for analysis were represented to consist of Nos. 1 and 2, ordinary commercial fertilizers containing nitrogen, No. 3, a rather superior sample of cottonseed meal, and No. 4, a nitrate mixed with sugar.

Careful analysis of the chemicals used in the Ruffle method showed them to contain a small percentage of nitrogen, which is allowed for in the following results:

Results according to the Ruffle Method.

	(a.)	(b.)	(c.)	Average
No. 1. Nitrogen found	1·83½	1·86	1·85	1·8483
No. 2. " "	2·15	2·16¼	2·15	2·1541
No. 3. " "	7·66½	7·57½	7·35	7·53
No. 4. " "	3·45	3·39½	3·35	3·3983

Results according to the Method with Soda Lime.

	(a.)	(b.)	(c.)	Average
No. 1. Nitrogen found	1·84	1·85	....	1·845
No. 2. " "	2·05	2·12½	.. .	2·0875
No. 3. " "	7·25	7·27½	. . .	7·2625
No. 4. " "	2·10	2·12½	. . .	2 0875

Results according to the Kjeldahl Method.

	(a.)	(b.)	(c.)	Average
No. 1. Nitrogen found	1·85	....	....	....
No. 2. " "	2·17½	....	....	....
No. 3. " "	7·33	....	....	....
No. 4. " "	....	....	....	....

From eight to ten hours' digestion with sulphuric acid was required in the Kjeldahl method, and about three-quarters of an hour for distillation, making it long and tedious. No. 4, consisting of sodium nitrate and sugar, yielded totally unreliable results, and is omitted. The quantity of material sent was too small to allow of other determinations.

The above determinations show the uniform and satisfactory results obtained by the Ruffle method, and commend it to the favorable consideration of agricultural chemists especially.

RESIN GAS FOR IRON MAKING.

Mr. H. C. Freeman, Alto Pass, Illinois, lately referred to an iron melting operation with gas, about thirty years ago, in Newark, New Jersey. Messrs. Bowen had a malleable iron foundry in that city, and, requiring very pure fuel for melting the pig metal (which was Salisbury, Conn., iron), they abandoned coal and substituted gas made from resin, which could then be had for about 50 cents a barrel. This fuel they used for several years, and, I think, up to the time of the war, when the advanced price compelled abandonment. The method of use was extremely simple. At the base of the furnace was arranged a sheet iron hearth, about four feet wide in front, nearly horizontal, and descending a little under the furnace. A man sat in front of the hearth and fed the resin with his hands, strewing it broadly over the hearth. The resin was broken to the size of one inch diameter and smaller. The downward radiated heat volatilized it.

* "Notes of Practical Work in State Laboratory, Auburn, Alabama."

A NEW METHOD OF MANUFACTURING CYLINDRICAL GLASS OBJECTS.

Mr. A. Oppermann, of Belgium, has recently patented a new and very ingenious method of manufacturing cylindrical glass objects, of any section whatever—the word cylinder being taken in its widest acceptation, and also designating a solid or hollow prism, and, indeed, even a plane sheet in the special case in which the directrix of the cylinder is reduced to a straight line. The most interesting, or, at least, the most immediate, application is in the manufacture of hollow cylinders of circular section, called "muffs" in the language of the trade, and which, when split lengthwise and spread out in a furnace, give the sheet glass used in windows.

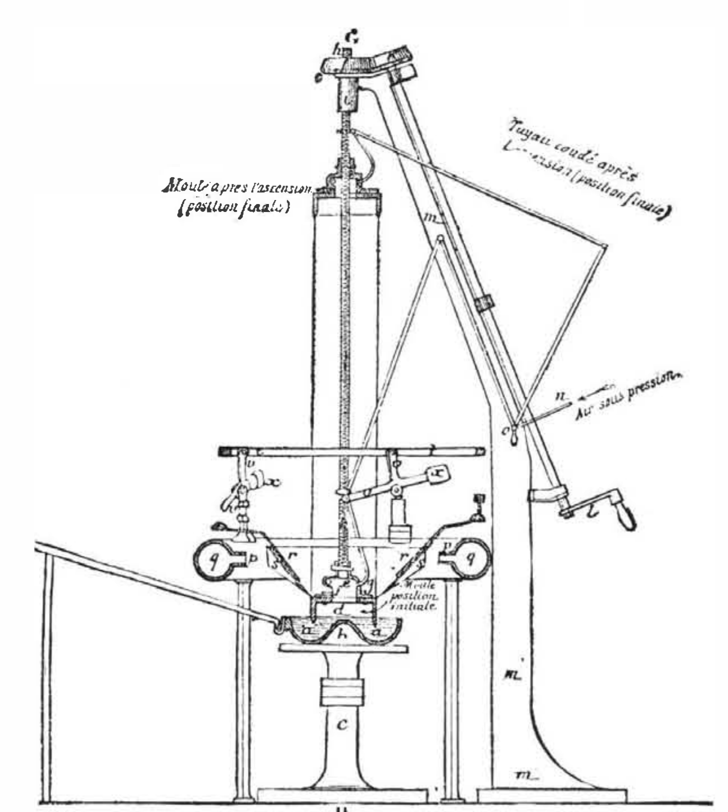
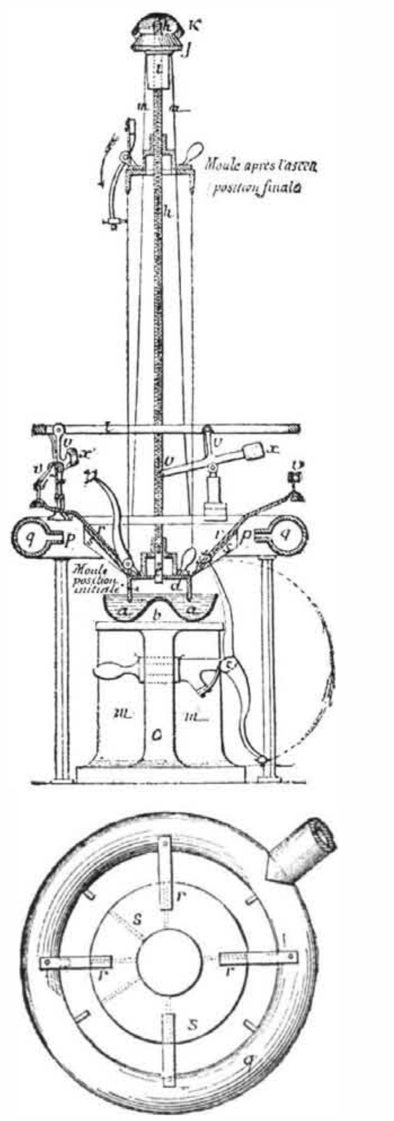
Every one knows the system that has been employed from time immemorial for producing the muff by *blowing*. In Mr. Oppermann's system, this blowing, with all its preliminaries and its multiple operations, which require numerous and experienced workmen, is entirely done away with. The principle of the method is that of *drawing* a mass of glass in a vertical direction through the aid of a mould of any form corresponding exactly to the section of the cylinder to be obtained. This mould is immersed in the molten glass, and an upward motion is given to it. The glass, in consequence of its cohesion and of its adherence to the mould, follows the latter in its ascensional motion, and forms a vertical sheet whose base is fixed, while the upper part rises with the mould itself.

The term mould is not exactly accurate; the device should be understood as a solid body—either of metal or refractory earth—whose lower face is a representation of the horizontal section of the cylinder with vertical generatrices.

Up till now, it has been a question merely of straight cylinders with an invariable directrix. But the introduction of air regulated at will permits of enlarging or reducing the cylinder that is being formed, to any desired degree—of enlarging it by the admission of compressed air, and of reducing it by the expansion due to the closing of the clack; whence, instead of cylinders with rectilinear generatrices, surfaces of revolution as variable as possible are obtained. Finally, the artificial cooling serves to regulate the thickness of the sides of the cylinder. It will be seen, in fact, that the glass will be less drawn out, and consequently thicker, the more it is cooled, and more drawn out, and consequently thinner, the less it is cooled.

When the operation of drawing is finished, the cylinder will be found fixed at its upper end to the face of the mould, and at its base to the glass remaining in the vessel. It may be detached by any artifice whatever—a hot glass thread, a cutting wheel, or a diamond. Mr. Oppermann's apparatus, however, includes a mechanical device for performing this. It consists of an arm carrying a cutting tool, pressed against the glass by a spring, and fixed upon a circle whose center coincides with the axis of the cylinder. A rotary motion given to the circle suffices to detach the cylinder at the top and bottom.

It now only remains to briefly describe the glass drawing apparatus.

GLASS DRAWING MACHINE.

Let us suppose a certain quantity of glass of the desired degree of fluidity to be contained in any receptacle whatever, and its free surface to be at rest and perfectly horizontal. If we lower the solid body in question until it touches the molten glass, and enters it to a certain depth, the glass will adhere to the parts that are in contact with it. If the body to whose face the glass adheres be then raised, the glass will be carried along in the ascensional motion, and the portion lifted will cool and solidify, and, performing of itself the office of mould for the rest of the bath, will carry along with it another portion of the glass, and so on, until the vessel is empty.

It will be understood that each point of the face of the mould gives rise to a vertical generatrix of the glass cylinder, and that, on varying the form of the face, cylinders of all forms may be obtained. If the mould touches the surface of the glass in the direction of a straight line, the cylinder will be reduced to a plane, and the operation described will give a sheet of glass. If the face is circular, the product will be a muff.

The principle of drawing has been applied for some time to the manufacture of glass rods and tubes. But the drawing in this case is in a horizontal direction, and is capable of producing nothing but objects of small dimensions.

During the formation of the cylinder, the parts of the glass carried along must, in measure as they leave the mass, cool and harden to the point necessary to allow them to carry along other portions of the glass in their train. Cooling through the surrounding air will sometimes be sufficient, and this is the case with rods and tubes; but Mr. Oppermann prefers artificial cooling through a blowing machine. In the manufacture of a hollow cylinder, he thus has a means of introducing air into the interior of it. In this case the mould is provided with a clack that opens inwardly, in order that the air may freely fill the cylinder in measure with its increase in size. On the contrary, this clack closes as soon as the air has a pressure greater than that of the external atmosphere.

The glass, *a*, held in a molten state in the circular vessel, *b*, provided with a detachable handle, is carried to the machine. The vessel rests upon a fixed platform, *c*. In case its weight, in addition to that of the glass, did not suffice to balance the upward traction resulting from the adhesion of the vitreous material to the mould, it would be fixed by bolts or some other method.

The mould is usually cylindrical in form, and, in order to facilitate the changing of the worn-out parts, is composed of two pieces, *d* and *e*, bolted together. The lower piece, *d*, has an edge which varies in sharpness according as it is desired to obtain a narrower or wider contact with the glass. The upper piece, *e*, is provided with a clack valve, *f*, for the admission of air into the interior of the muff, and receives the extremity of the tube, *g*, that leads the air under pressure into the mould. This tube is fixed to the rod, *h*, which carries the mould. This rod is threaded throughout its entire length, and passes into a vertical nut, *i*, which is fixed to the frame of the apparatus, and which can only revolve. The rotary motion is communicated by a pair of bevel wheels, *j* and *k*, actuated by an inclined shaft, provided with a hand winch, *l*. The cast iron frame, *m*, supports the entire transmission. It will be seen that the nut, on revolving, will move the rod that carries the mould, whence the vertical motion of the latter in one direction or the other.

The air, under pressure, is led into the mould through the movable tube, *g*, and the fixed one, *n*, which carries a cock, *o*, for regulating the supply.

When, on the external cooling of the cylinder, the air designed to effect such cooling issues from the tubulures, *p*, in the circular conduit, *q*, it strikes a movable sheet iron cone, *r*, whose position must be so regulated as to lead refrigerant jets of air upon a zone more or less distant from the molten glass. These jets are directed by radial vanes, *s*. In order to raise or lower the cone, we act upon the iron circle, *t*, which actuates the levers *v*, and, through their intermedium, the cone itself, which is balanced by the counterpoise, *x*. The circular conduit supports the apparatus.

The characteristic part of this invention is the draw-

ing of the glass with artificial cooling, whatever be the style of the apparatus.

If plate glass is to be manufactured, without the intermediate form of muff, a trough-shaped vessel is substituted for the circular one, and the mould is given the form of a straight ruler with a more or less marked chamfer, in order to bring about a contact with the vitreous material.

If a rotary motion be given to the muff or to the platform that supports the vessel of molten glass, spirally twisted cylinders will be obtained.

If, for plain glass, glass of several different colors be substituted, and be superposed in the vessel, it will be possible to make cylinders whose section will exhibit several tints. In this case, the lower edge of the mould will have to pass through the various layers of glass before beginning its ascensional motion.—*Le Genie Civil.*

WROUGHT IRON.*

By J. STARKIE GARDNER.

THE subject of "wrought iron" presents so many aspects that it is not easy to settle how best to treat it within the time at our disposal. I presume that I have been invited here as an employer of blacksmiths, to give you the results of my experience in that capacity; but I do not think that an evening would be so profitably spent in merely describing the practice of smithing, in the absence of forges to illustrate the process, as in a more comprehensive view of the whole subject.

I may assume that the majority present do not require to be told anything about either the sources or the production of iron, but for the benefit of the rest I would crave a few moments' patience while I endeavor to put them in possession of just sufficient information to enable every one, whether well informed at the outset or the reverse, to leave off with a clear conception of the subject.

There are some reasons for inferring that iron, as met with in the principal ores known to us, is no longer in the normal state, and that man, in rendering it molten, is at infinite pains to restore the metal to a purity which it only lost in entering into the composition of that merely superficial crust of the earth in which we find it. Nearly pure native iron has been brought up in the basalts and gabbros of those deeply seated by-gone eruptions which for magnitude contrasted with those actually witnessed by man as the gash of a razor to the prick of a pin. Masses of native iron up to 50,000 lb. weight were found on the beach of Disko Island by Baron Nordenskiold, which were unquestionably derived from the adjacent basalt; while the samples from other bodies in space, which frequently reach us in the form of meteorites, though composed wholly of terrestrial elements, sufficiently prove that the abundant iron in them has not undergone those changes which the presence of oxygen, carbon, etc., in the crust of our earth have brought about. The known density of the earth, the composition of the sun, the magnetite and Titanic iron of our lavas, go far to indicate the possibility of the existence of masses of perhaps native iron at some depth toward the interior of the earth, and the erupted lavas may even, by a flight of the imagination, be likened to the slags from smelting furnaces. This fanciful resemblance is indeed heightened by the occasional reproduction in the latter of quartz, compact silica, garnets, augite, and other natural products familiarly met with in the former.

For the present, however, our supplies are mainly derived indirectly from the wearing away of erupted rocks and the redeposition of their material, after being subjected to various kinds of sorting processes, as sedimentary rock. We can choose for our manufacture iron in combination with oxygen, such as hematites, limonites, bog ores, etc., or with carbon, such as clay ironstone or spathic ore. The choice is great, for all the resources of nature's laboratory, heat, pressure, solution, precipitation, have been at work for countless ages, resulting in endless combinations with the varied elements with which the iron has been brought in contact, so that the existing varieties of oxides, carbonates, phosphates, and sulphides are innumerable. We use them indifferently, whether derived from Palæozoic rocks formed myriads of ages ago, or lake ores formed within the lives of living people, and they are so abundant that, unlike coal, there is no fear that the supply will ever come to an end.

These impure ores are brought back to a relatively pure state by the process of smelting in brick furnaces supplied with fuel and continuous blasts of heated air. The ore is generally calcined, and the furnaces are fed with it and coal, in the proportion of about three parts of fuel to one of ore, and with a certain proportion of limestone as a purifier or flux, for the removal of the earthy matter of the ore. The metal, being the heaviest, drains to the bottom when fused, and is run off into moulds, when it becomes pig iron, and is ready for use in foundries; but it has taken up too much carbon from the fuel to be available at once for the manufacture of wrought iron, and must, therefore, be subjected to various further purifying processes. Until coal came into general use, these further processes were not separated from the smelting, and malleable iron was produced direct from the ore with charcoal fuel by continuous working, and to some extent by the further subsequent manipulation of the smith.

The operation must at first have been of the simplest kind, the apparatus employed having probably resembled some of the primitive furnaces described by Dr. Percy as still in use in India, which consist simply of a closed hearth of carefully dried clay, and bellows.† Dr. Percy believes, however, that as early as the time of the Roman occupation of Britain, the ore was reduced in somewhat larger furnaces, and by a process which he distinguishes as the Catalan.‡ The iron was not actually rendered molten, but was separated out and made to coalesce into a solid lump while in a pasty condition, and was taken out sufficiently free from carbon to be at once malleable. It was then placed under a tilt hammer weighing from 1,200 lb. to 1,500 lb., worked by a rough cog wheel, and driven by water power.

Prof. Roberts-Austen informs me that the use of such hammers was very common in Surrey and Sussex, and that the name "hammer pond" still denotes, in many places, the artificial pond which supplied the water power. It was beaten into bars on a slightly tapering anvil, about 27 in. long and 10 in. wide, and was in all probability worked into sizes roughly to suit the smith's requirements. The data, unfortunately, for tracing the actual steps in the history of the production of iron in the middle ages do not exist or are unknown to me; but the change in the style of smith's work in the 15th century, when high railings with ponderous angle-bars came into vogue, no doubt resulted from, or necessitated, a change in the manufacture of the raw material. The occurrence of a cast-iron tombstone in Burwash Church, Sussex, believed to date from the 14th century, clearly shows indeed that some more advanced form of furnace must have been in use at that time. Blast furnaces originated, according to Dr. Percy (*loc. cit.*, p. 571), in the district of Siegen, Prussia, in the beginning of the 15th century; but the Stuckofen, which he describes as a Catalan forge extended upward into a shaft (p. 319), must have been of earlier date, and was capable of producing both cast and malleable iron. Another ancient form, intermediate between the Catalan and the blast furnace, is the Swedish "Osmund" furnace, used in 1864, and perhaps even now, which produced either a lump of malleable iron or fluid cast iron, by varying the proportion of fuel to ore in the charge. It seems probable that by the time of Elizabeth the high blast furnace had generally superseded those in which malleable iron was directly produced, for cast cannon, firebacks, andirons, etc., in general use. In 1676, we read that the pig-iron was taken from the blast furnace to the open hearth charcoal finery, softened, and worked into a lump. "This they take out, and giving it a few strokes with their sledges, they carry it to a great weighty hammer, raised likewise by the motion of a water wheel, where applying it dexterously to the blows, they presently beat it out into a thick short square. This they put into the finery again, and heating it red hot, they work it out under the same hammer, till it comes into the shape of a bar in the middle with two square knobs at the ends. Last of all, they give it other heatings in the chafery, and more workings under the hammer, till they have brought their iron into bars of several shapes and sizes, in which fashion they expose them to sale."*

It is scarcely probable that these fineries turned out more than from two to four tons of metal per week, and the production of iron in England was not estimated at more than 17,000 tons per annum, until the discovery that it could be smelted with coal, instead of charcoal, gave the industry an enormous impetus. Though the first patent for this is dated 1611, none seems to have been actually used till Dudley succeeded in working the invention profitably in 1620.† The merit of completely solving the problem belongs, however, to Mr. Darby, who introduced its use in the Coalbrookdale Iron Works in 1720.

Pig iron, as produced in the blast furnace, contains a percentage of carbon that renders it unworkable, and has to be removed by the action of oxygen at a high temperature.

Before the discovery of puddling, the pig was worked into malleable iron in a charcoal finery in contact with the fuel and under a blast of air. It was not perfectly remelted, but fused into one or two lumps, and hammered under a heavy forge hammer, and then drawn out into bars under the lighter and more quickly moving tilt hammer. Reheating was accomplished in a sort of blacksmith's forge, and mineral fuel was not used because the sulphide contained in it injured the iron.‡

Puddling was patented by Cort in 1784, and consists in heating the iron on the bed of a reverberating furnace, in which it does not come into direct contact with the fuel, and stirring it until it is decarburized, partly by the action of the oxygen of the air, and partly by that of the cinder added during the process. The iron leaves the puddling furnace as a spongy mass, consisting of particles of malleable iron, feebly cohering, and infiltrated throughout with liquid cinder. By hammering, these particles are welded into a solid rectangular slab, and the cinder, more or less, completely squeezed out. This process is called shingling, and was formerly the only one used for producing bar iron (Percy, *loc. cit.*, p. 693). Lever or tilt and helve hammers were always used, the latter weighing as much as ten tons, until the introduction of the stamp hammer, with vertical action, and particularly of the Nasmyth hammer, in 1842. During the present century, squeezing has been partially substituted for shingling, and the iron is pressed under rolls into flat bars 14 ft. to 18 ft. long, and ¾ in. thick by 3 in. to 5 in. wide. The iron is now ready for the final process, which is to convert it into merchantable iron. The puddled bars are cut by shears into short pieces, varying in length according to requirements, which are piled in packets, raised to a welding heat in a special furnace, and then rolled into bars, or sometimes hammered before rolling (Percy, *loc. cit.*, p. 712). Sheet iron may require heating and rolling as many as six times before the finished plate is produced, and there are special slitting mills for slitting bar iron into nail rods, etc.

These sheets and bars are stocked by the merchants supplying the blacksmith, who requires, perhaps, so insignificant a quantity of each kind that his orders would be ignored at the mills, where they roll in bulk. It is computed that there are a thousand different sections of wrought iron in the market for smithing, and it would be useless for the blacksmith to attempt to hold any great stock, as he cannot tell till the commission is received what size he will need. The choice is increased by the number of different qualities purchasable at different prices, such as Welsh, South Staffordshire, Swedish, Russian, or the high priced Lowmoor iron of South Yorkshire, made with extreme care, and excellent for decorative use.

Such are the conditions of the industry at the present day; but before entering into the more important subject—the manipulation of the iron by the smith—we must glance for a few moments at its history.

The inquiry into the beginning of the use of iron is a purely academical one. Iron rusts rapidly, and the delicate gold or bronze enrichment of a sword or cap are exhumed in perfect preservation, while the blade or helm is only traceable in a trail of rust. The use of iron dates back to prehistoric periods, and the seeming preference shown by Celts and other nations for bronze weapons may have been less due to ignorance regarding the production of iron than to want of knowledge as to the art of tempering it. Dr. Percy thinks from the ease with which it can be reduced from the ore, that the use of iron must have preceded that of bronze, which is an alloy of at least two metals requiring a higher degree of skill to produce. Dr. John Evans, on the other hand, is, I believe, of opinion that copper and tin, whose native ores are far purer and more metallic looking than the almost earthy ores of iron, would have been first to attract attention. However this may be, the virgin iron of meteoric origin must have been highly prized indeed, and these unearthly visitors, with their mysterious origin, must have been as welcome to the savage as nuggets of virgin gold dropped from the skies would be to civilized man. It was given as prizes by the Greeks, and their word σίδηρος, iron, seems to imply the knowledge that it had fallen from the skies, and to be genetically connected with the Latin *sidus*, a star. Its value has not lessened, for the man of science weighs it grain by grain, and pays its weight in gold.* A whole volume has been written on the early history of iron, bringing it only down to the time of the Romans ("La Ferronnerie," vol. i.; F. Liger, Paris, 1873). The history of its early production is, however, very obscure, and so far as England is concerned, we can only say that there are strong grounds for inferring that the ancient Britons manufactured it on a small scale, and that under the Romans its use was greatly extended. Traces of their forges abound in the Weald of Kent and Sussex, and the Forest of Dean; but slags are also picked up in counties where there is not the remotest tradition of iron having ever been manufactured.† The further development of its history will be dealt with presently.

The subject "wrought iron" would comprise, if followed out in detail, a description of the industries of the cutlers, ironmongers, armorers, farriers, fletchers, and spurriers, as well as the blacksmiths, so that the workers in iron were a formidable body in mediæval times, and formed several powerful guilds with exceptional privileges. The blacksmiths of London in 1376 were second to none, and sent the fullest number (six representatives) to the municipal common council. Their art can alone be briefly traced to-night, and even then our limits exclude any reference to it as practiced in Germany, Italy, and Spain, and the East, though these countries excelled our own in the middle ages. We must further omit all reference to locks, keys, handles, and other small work, and to the arts of inlaying, damascening, etc., which, exquisite though they be, were produced rather by jewelers' methods than those of the brawny smith.

It is perfectly obvious, from what has been said previously, that the smith of to-day has a much easier task than his predecessors of the middle ages. It appears impossible to trace the exact forms of the bars which found their way to market from the Forest of Dean or the Weald of Sussex, say in the days of Elizabeth; but considering that the bars had to be beaten out, as we have seen, on an anvil under the relatively primitive tilt hammer, it is improbable that any great variety of section was produced, or that the angles of the bars were mathematically true. The "bars" were in fact probably analogous to the "puddle bars" of to-day, that is, very elongated ingots ready to be fashioned into finished bars, but not themselves available to be cut up and used without labor, like the bars from the rolling mills at the present day. The fact alone that the smith had to beat out most of the sections himself in the middle ages has caused a most pronounced difference between mediæval and 19th century smiths' work, and must ever be kept in mind in contrasting together the work of such widely different ages. Few of us probably sympathize with those who affect to prefer, as a matter of taste, the ugliest old production to the most beautiful modern one, but it is perfectly true of old ironwork that it possesses interest

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* A recent lecture before the Society of Arts, London. From the *Journal* of the Society.

† The simplest described furnace is of clay, carefully dried by fire, and is two to four feet high, with two holes for the earthern pipes or tuyeres which convey the blast, and a hole on the opposite side for the removal of cinder. It is filled with charcoal and lighted, and as this becomes consumed and sinks, the ore is supplied until the full charge is reached. The bellows are worked the whole time, and at the end of four to six hours a small mass of malleable iron is removed, and if sufficiently hot, at once hammered into a bloom. There is no division of labor, and the smelters are itinerant, going from village to village, and setting up their furnace wherever a demand for iron exists, and a supply of iron and charcoal can be obtained. (Percy's "Metallurgy—Iron and Steel," 1864, p. 257.)

‡ Dr. Percy says: "The metal was obtained by a method no doubt closely resembling, if not identical with, the Catalan process" (*loc. cit.*, p. 876). Neglecting all details of construction, for which the original work (p. 278) must be consulted, this furnace may be described as a rectangular cavity or hearth, of various dimensions, within a building. Three sides were formed mainly of iron and clay, and the fourth of stones luted with clay, while the bottom consisted of a flat or slightly hollowed refractory stone, such as granite. On one side the tuyere passes through a small arched opening about eighteen or nineteen inches from the bottom. There was no chimney, but a hole was left in the roof. A Catalan forge employed ten men in France. The ore is first crushed under a hammer and sifted. The furnace is heated with charcoal, which is packed almost as high as the bottom of the tuyere, when alternate layers of ore siftings and charcoal are piled up so as to form a ridge, one slope of which is covered with moistened charcoal breeze, beaten well down with a spade. The blast is turned on, and the level kept up by additions of ore and charcoal. At the end of about six hours the iron has coalesced into a solid lump at the bottom, which is lifted over the edge of the furnace by levers and is ready for hammering.

* "An Account of the Ironworks in the Forest of Dean," by Henry Poole, Esq. "Philosophical Transactions," vol. xi., p. 391, 1676.

† "An Account of the Ironworks in the Forest of Dean," by Henry Poole, contained in the "Philosophical Transactions" for 1676, seems to contradict this. As quoted by Percy, *loc. cit.*, pp. 590 and 886, it states that though charcoal was used in the blast furnaces, sea coal was the fuel used in the open hearth or finery, and in the chafery or reheating forge. Swedish and other charcoal iron is still made in direct contact with charcoal fuel.

‡ A bar of Swedish iron 12 feet long and weighing 60 lb. is heated six or eight times while being drawn out under the tilt hammers moved by water power. This refining process with charcoal alone required 20 to 30 cubic feet of fuel to produce 100 lb. of iron.

* *Meteorites.*—See "An Introduction to the Study of Meteorites," printed by order of the Trustees of the British Museum, 1886, price 2d. This work contains the best information on the subject, in a most concise and unpretending form. From it we learn that the siderites contain 80 to 95 per cent. of iron and 6 to 10 per cent. of nickel. The large quantity of nickel gives the metal a silvery look, and preserves it to a large extent from rust. This class of meteorite is rarer than the stony varieties called aerolites, and but few (only eight) have been actually seen to fall.

Value of Meteorites.—Mr. Bryce-Wright, the well known mineralogist, informs me that the prices of meteorites range from £3 or £4 per lb. weight to as much as £12 per ounce—such as the Wold Cottage meteorite of Yorkshire. Some of the Russian meteorites are worth £5 to £6 the ounce, and the prices generally have been trebled within the last few years. As much as £1 for a few grains of the rarer meteorites has been paid to Professor Charles Upham Shepard, of Amherst College, U. S.—Bryce-Wright, *in. lit.*, January 26, 1887.

Meteoric Dust.—In addition to our almost illimitable terrestrial stores, we are receiving continuous, though minute, supplementary supplies from space in the form of meteoric dust, which, though impalpable to us here, can be collected on the snows of Greenland and the higher ranges of mountains, and enters perceptibly into the composition of the sediments of the greatest depths of the ocean.

† Mr. Whitaker, of the Geological Survey, has frequently picked up iron slags in Norfolk and other counties that are not known to have produced iron.

and attractions which few examples of modern work can possibly equal.

If you enter a cathedral where some happily surviving antiquity has been made the theme for reproduction in modern times, such as the grill work in Canterbury, Winchester, or Chichester cathedrals, you immediately become conscious, without being an antiquary or specialist, and without being able at first perhaps to define precisely why, which is the old and which the new. The explanation is simply that the olden time smith cut a piece from his shingled bar, which he judged by the eye would beat out into a rod of a given length, and curl up into a scroll of the desired form. More or less sufficed for him, and by his method of work, he produced an irregularity and play in even the most monotonous design which is artistically charming to us, but which was perhaps even a source of chagrin to himself. The modern smith, on the other hand, when he receives a commission, buys the required number of rods, cuts them up into pieces of exactly the same length, makes a standard pattern, and if there is much repetition, a tool to gauge the scrolls and insure their uniformity. If there is any irregularity it is considered bad smithing, and if under the conditions it is the result of mere carelessness, the result may be inartistic. The aversion to straight bars seen in the oldest examples was also probably due to the fact that perhaps the most difficult task that could be set a primitive smith was to handle a long heavy bar and to beat it out perfectly true with mathematically exact and sharp angles.

Another reason for the generally artistic superiority of the old work may have been that it was only intrusted to those who had a special aptitude, and if such a workman was not forthcoming, the work was either not executed, or was made in the simplest form; while if he were forthcoming, the details at least of the design were left to his own fancy, and were, therefore, well within his own powers. In other words, it was the existence of the skilled smith that created the demand, rather than the demand that created the smith, and it seems a reasonable inference that none such had to beg for work in the middle ages. When a grill was wanted for Westminster Abbey, it was not the local man who had the commission, but a smith from Leighton, or a smith from Lewes, was fetched and maintained until the task was completed. Finally, it is only reasonable to suppose that the smiths of those days were not fettered by estimate or bound by time, and that the art work was produced for art's sake, by a genuine artist, whose brains were not picked, as in these competitive days, by a crowd of imitators who copy every original design that is accessible, until the originator is weary of his happiest ideas before he has been able to derive any adequate benefit from them.

Those who have stood by the forge, and watched the sparks fly as the skillful smith deftly beats, and twists, and combines his iron, would think it the easiest of all crafts. But who, standing by the side of the musician as he draws his bow across the chords of his violin, would realize the patient study and dexterity required before he is able to make it respond at will? As no practice or teaching can make a musician unless he have an ear for music, so can no one really excel in the manipulation of iron unless he possess special aptitude. His tools are as primitive as those of the sculptor, and with hammer and anvil, forge and bellows, a bench, a vise, and a few chisels, he has to produce out of the stubborn iron effects that may rival the work of the loom in delicacy, or form the massive entrance gates to a palace or a park. It is so simple a business that the total cost of setting up a forge, exclusive of rent, need not exceed £20.

When rolled or beaten, iron acquires a fibrous texture which it does not possess when first cast into ingots, and which contributes toward its acknowledged superiority over cast iron, where the latter is not used in considerable bulk. Another quality possessed by this fibrous iron is malleability, which enables a bar to be flattened out or rolled up into any desired form; and yet another, ductility, which enables a thick bar to be drawn out into an attenuated wire. Finally, fibrous iron possesses the valuable property called welding, or, in other words, of uniting under pressure at a heat far below its melting point. All these properties combine to make it possible to produce effects with iron which it is almost impossible to produce in other metals, and without which the fine art of smithing would never have come into existence. The separate pieces as they leave the forge may also either be fixed together by straps of hot iron tied round them, or by bolts and rivets, or by brass or silver solder.

The first thing the modern smith requires is a design, and very often a working drawing showing the exact sizes of iron to be used, and the method of fixing them together. Some day, perhaps, our training schools may turn out a class of artisans such as exists in France and Italy, capable of designing as well as accomplishing the manual labor. One cannot but believe, so practical are the old designs, that in most cases they were created by the smith who executed the work, after merely a consultation with the architect. The few smiths who can do this now work at a disadvantage, as, unless the artist who makes their working drawings has a thoroughly practical knowledge of the craft, he will introduce needless difficulties and intricacies which render the work unnecessarily expensive.

It would be wearisome to describe in detail all the smith's cunning. I propose instead to treat some of the leading classes of mediæval ironwork as they appeared chronologically, and to give you a general idea as to how they were fashioned as we go on. It will be recollected that our examples are drawn from England only, with this exception, that mediæval ironwork being none too plentiful, the English examples have been supplemented by others from Western France, which was politically and artistically connected so closely with us down to the 16th century that our arts and architecture were practically one.

The earliest works in iron either existing or known in this country are the hinges to doors, but that iron was put to multifarious uses is sufficiently apparent. The eminent antiquary Dr. Parker is indeed of opinion that metal work led the way in art, and was far in advance of the contemporary mason's work. He has kindly pointed out to me that in the Cædmon MS. of the date 1006 to 1012, the capitals and mouldings of the columns are represented by the illuminator as of metal work of most exquisite character, and that the type pattern is that of the rich 13th century foliage, showing that, during the intervening centuries, this mode of ornamentation was kept in view. From these and other considerations, he infers that the art of metal working was not only in a very relatively advanced state during our Saxon period, but retained much of the same character in the next succeeding centuries.

We are, indeed, entirely baffled when we attempt to trace the origin of the different types of hinges that prevailed in the 12th and 13th centuries. Go back as we may, it seems impossible to predicate that any one form is earlier than another. The Cotton and Cædmon manuscripts, which belong to the 10th, 11th, and 12th centuries, alone exhibit so many distinct types that it is perfectly obvious that the art of making highly decorative hinges was very far indeed from being in its infancy. They also clearly prove, as pointed out by Dr. Parker, that the Norman types of hinge are derived and imitated from the Saxon, and consequently also that the ruder types, such as that at Sempringham, instead of being the most ancient, are simply the coarser productions of less skilled smiths. In like manner, we find in remote places that styles and methods survive long after they have been abandoned in the busier centers. Thus in quaint Dartmouth there are some very mediæval looking hinges on a church door which bears the date 1631, in iron of exactly the same style as the hinge.

The hinges are thus of extreme interest as the best existing representatives of early smithing left to us, and so many examples have escaped probably because they were closely affixed to doors, were thoroughly protected by paint, and being useful objects as well as ornamental, were rescued and applied to new doors when the old woodwork decayed. Their removal was, moreover, a tough job, which presented no temptations to the iconoclast. The hinges to cope closets, presses, etc., were no less beautiful and of the same types. In addition to the hinges, the doors were decorated with strengthening bars, handles, escutcheons, bolts, lock plates, nails, etc., all of similar character

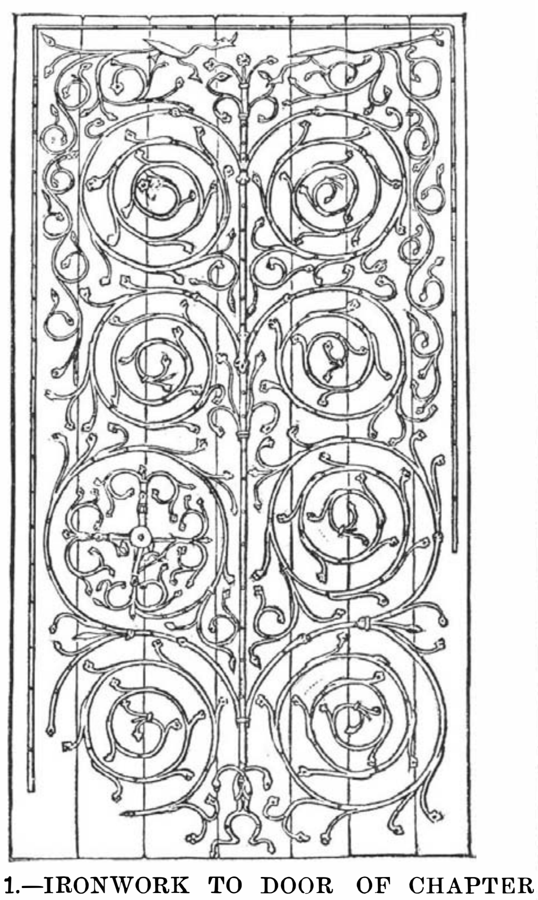


FIG. 1.—IRONWORK TO DOOR OF CHAPTER HOUSE, YORK CATHEDRAL; THIRTEENTH CENTURY.

and beauty. We must be content with a very few examples, which, for reasons explained, need not be selected with any regard to date.

The finest examples in the world probably, and certainly within the geographical limits laid down, are those of Notre Dame of Paris. The stubborn iron seems to have been as pliable under the smith's hands as silken thread. The massive doors are almost entirely concealed, and no two pieces of ornament are similar. Indeed, the dissimilarity is almost too apparent, and somewhat mars the symmetry of the design. The *motif* is supposed to be the terrestrial paradise with its foliage sheltering innumerable birds, dragons, and other fantastic beings. There are no similar decorative hinges to the center door, though this has been lately furnished with clever reproductions, and if any were originally executed for it, they would have been, if possible, even more elaborate. It is unfortunate that nothing is actually known about them, but they are pronounced by all competent judges to be 12th or early 13th century work, and it is quite obvious that their attribution to Biscornet, a 16th century smith, is a mere fable. This had taken such a hold, however, that Mathurin Jousse de la Fleche (La Fidele ouverture de l'art du serrurier, 1627) regrets that Biscornet had not divulged the secret of running iron as other fusible metals. No higher tribute could be paid than this confession by the most noted smith of his day that he was unable to conceive that anything so rich could possibly have been forged, and that he was driven to suppose they had been cast by some utterly lost process.

We have no work in England of the same kind that can possibly be held to rival them, but the famous door in St. George's Chapel, Windsor, is of about the same date, and has been placed second to them by some. The two leaves of the doors are in this case completely covered on the inside with a flowing design, which might be Italian, so free is it from conventional stiffness, and they are certainly as fine as any specimens in this country, if not finer. The illustration of these could not be finished in time to throw on the screen, but a partly finished drawing is exhibited.

Another good example, of a not uncommon type, is that on the inside of a door in York Cathedral, leading to the chapter house. Like that at Windsor, the work has no connection whatever with the hinges, and seems merely designed to tie the wooden planks together, and to give the whole extra strength. The design is a central stem, giving off four large scrolls on each side, from which little leaves branch copiously in all directions, though always springing from the outer curve. The pretty feature is the way the whole of the inner volutes of one scroll are removed to make room for an open basket-like handle, reminding one of the basket hilts of a Ferrara or Toledo rapier. True, hinges of precisely similar kind of work exist at Eaton Bray and St. Mary's, Norwich.

A still more elegant design, however, is that of which there are casts in the Tufnell Street Museum, and an illustration in Raymond Bordeaux's work on hinges. These are the hinges at Worksop Priory, Notts, and their charm lies in the fact that every scroll terminates in various beautiful representations of the iris flower. They are fixed to a cedar wood door, and considered to be of the 12th century. The form of the iris is evidently taken directly from nature, for the pistils and stamens are faithfully represented, and the design is doubtless older than the conventional fleur-de-lis.

I have also selected the Durham cathedral hinges as a good typical example of Norman work, and because in my hasty studies I have not as yet come across any published illustration of them. They are simple yet beautiful in themselves, but the door is more remarkable for the sumptuous character of the ironwork between the hinges, the leading lines of which are unusual. Canon Greenwell informs me that the stonework dates from 1135, but that he would place the date

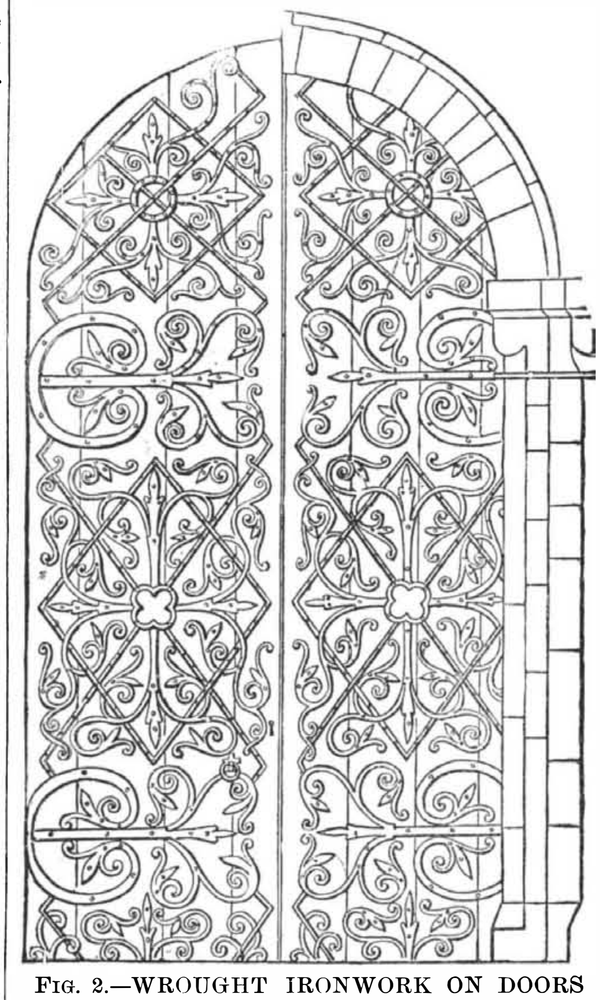


FIG. 2.—WROUGHT IRONWORK ON DOORS TO CLOISTER, DURHAM CATHEDRAL; TWELFTH CENTURY.

of the ironwork toward the end of the 12th century. The pattern of the ironwork on the corresponding north door can be made out in a good light, though the iron has long since vanished. The celebrated sanctuary knocker is on a different door, and of bronze.

Other exquisite examples on the cope chests in York Cathedral have only recently been illustrated. There are two chests side by side, one covered with rich and bold masculine scrollwork, and the other with a delicate feminine flowery pattern. The contrast could not have been accidental, and besides serving to distinguish the chests, is of the kind which prompts one sheriff of London to select a massy green and gold livery for his state coach and the other a more delicate foil in blue and silver. Almost the same two designs occur, though not quite in juxtaposition, in Sens Cathedral, confirming the view that the smiths were artists enough to recognize the value of complementary design. The Dean of York informs me that nothing whatever is known as to the history of these chests.

In hinges, in our country at least, strength was rarely sacrificed to ornament, while in some exposed places ornament was very properly sacrificed to strength. The fitness of the object to its purpose was the primary intention, and hence the forms they assume are in most cases very pleasing. There was no concealment as to the construction of the door, and every requisite detail was utilized as ornament, and, as my friend Mr. George Birch so eloquently put it in a lecture in this room, "the very nail heads were things of beauty." They were seldom wrought in high relief, as in the splendid example from Hal, in Flanders, exhibited as a cast in the South Kensington Museum; but grooving and a little incising are common features, while the modeling of the foliage, dragons' heads, etc., of such types as York and Chester is in relatively low relief.

Now, if I were to attempt to tell you how these hinges were made, you might very properly ask me how I knew; but I can describe most minutely the manufacture of a similar hinge made the day before yesterday under my own eyes. Hinge work is, perhaps, the one branch of smithing in which the smith of to-day stands in absolutely the same position as the smith

of eight centuries ago. Rolling mills have done nothing to lessen his task, and no sections of iron can be bought ready made that are of much avail. Here is a simple hinge designed in the style of the 16th century, by Messrs. George and Peto, and made without a weld; and here a fine example of a highly decorative hinge of the 14th century character, designed by Mr. Oldrid Scott. As welding has been extensively used in its production, I had better at once describe that process. The separate parts to be welded are raised to a white heat, and become soft and pasty. When in this condition, they cannot be exposed for an instant to the atmosphere without superficial oxidation, and however quickly they may be brought to the anvil, a scale is formed. A little silver sand has, however, been sprinkled on them in the forge, which converts the oxide into a very fusible and liquid silicate of protoxide, and when the two pieces of iron are brought together, and sharply hammered, the melted scale is extruded in showers of sparks, and the clean metallic surfaces unite. A good weld requires an expert smith, and a clumsy one will let the iron burn, when no proper weld can be accomplished.

Welding is the A B C of smithing. I have marked the hinge across in red wherever it was necessary to weld it, and you will see that it has undergone the operation fully twenty times. This excessive number of welds is really easier and quicker than tapering it down from any bar that can be bought. The leaves are hammered out flat, and shaped with a chisel, and the half round of the stems is produced by a steel punch hollowed out and hammered on to the bar while hot.

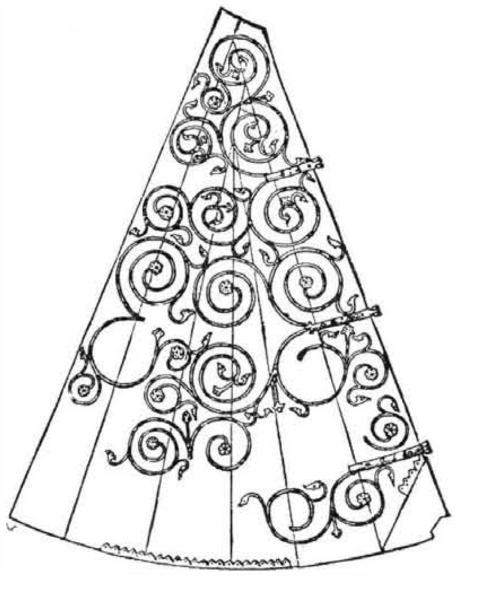


FIG. 3.—HALF OF A COPE CHEST IN YORK CATHEDRAL; THIRTEENTH CENTURY WORK.

The highly decorative hinges were gilt, and laid, it appears, on skins, and sometimes felt, dyed scarlet, and not directly on the wood. They fell into disuse in England during the 15th and 16th centuries, when the woodwork of doors became richly moulded and carved. But in Germany their use was continued, though thin *repousse* work was made to supply the ornamentation at a less cost, and without welds. The German work was often tinned, and also laid on a scarlet ground.

It is impossible to quit the subject of hinges without a brief reference to the mediæval safes, of which so many examples are preserved. They have been thoroughly dealt with by Mr. E. C. Robins, F.S.A. In these chests the key shot sometimes as many as twenty-four bolts, and the size of the lock was only limited by the dimensions of the lid of the chest. The ordinary type is square, with massive iron binding, and decorated with the painted armorial bearings of the owner.

When we reflect that there were no insurance offices or banks, and neither check books nor paper money, we can readily understand that a prince or plutocrat would not be nice as to the cost of the strong box which was to contain all his worldly wealth.

The few still existing cathedral grills of the middle ages appeal to us as more important monuments of the smith's work than door furniture. They are more interesting and more varied, and are so few in number that I can describe them in detail.

Visitors to Winchester will have noticed, in a corner of the nave, a door patched up of four odd pieces of grill work. This, from its style, I should judge to be the oldest piece of grill work in England. The design is composed of sprays formed of two rows of scrolls welded to a central stem, like a much curled ostrich feather, with lesser scrolls in the interstices, and the major scrolls each terminating in an open work trefoil or quinquefoil. The large scrolls are 5½ in. in diameter, and rather stout, the grill possessing great resisting power, though it would not be hard to climb. The dean has kindly informed me that before the destruction of St. Swithin's shrine it was placed at the head of the stone steps which lead up from the south transept to the ambulatory, and here the places where it was fastened into the piers at either side are still quite easily to be traced. The dean hopes some day to replace them there. "Their use was a characteristic one. There came crowds of pilgrims to worship at St. Swithin's shrine. And here, as elsewhere, the monks knew quite well that these devout people carried all kinds of dirt and infection about with them; consequently they rigidly excluded them from the choir, south transept, and nave, and made them enter and depart by the Norman doorway in the north transept. This grill blocked their way. They could get round far enough to see the splendor of the high altar, etc., and then had to return the way they came.

"From St. Swithin's the good pilgrims always went on (if they went further) to St. Thomas of Canterbury; so that from this point they were true Canterbury pilgrims of the Southeast road—not, of course, along Chaucer's way." There is, unfortunately, no means of fixing the date, since no other grill resembles it; but, from the position indicated in the cathedral, it may well have been made as long ago as the 11th or 12th century.

Viollet le Duc figures one from the Cathedral of Puy-en-Velay somewhat like it, which, he considers, dates from the beginning of the 12th century. In both cases many of the scrolls are welded together, and in the French example the face of the scrolls is covered with dotted ornament. Another grill of the same class is that of the Eglise De Conques, the design of which is more varied; and which possesses in addition a really formidable chevaux-de-frise of barbed spikes pointing downward, a little below the cresting, which is itself made up of alternating greater and less, barbed, arrow headed spikes. This would be as difficult to climb as anything of the sort could be. It is ascribed to the end of the 12th or beginning of the 13th century, and, like many of the later grills and most hinges of the period, has dragons' heads introduced into the design. Another grill of the same class has been figured by Didron in the "Annales Archeologiques," in which the design is still richer. This class of grills possessed great strength, and yet appeared extremely light. They do not correspond in the least in their lines to the masons' or joiners' work of their period, and the designs appear to have been arrived at independently by the simple process of scrolling up bars of iron of various lengths at both ends, and combining them into pleasing forms to fill in given spaces, and then welding and bolting them up together, and finally fixing them into frames.

Another class of grill which overlapped these in date, but was on the whole typical of a somewhat later period, was composed principally of a vast number of simple scrolls of small size, placed back to back and collared together. These were easier and took less time to make, requiring, indeed, but little of the smith's skill. They were transparent, yet full of resisting power; they were lofty, not easy to climb, and, unless filling in an opening in masonry, always surmounted by a cresting in some form of spikes.

The choir screen at Lincoln is the most perfect type of its class in existence. The date was said by the vergers of the cathedral to be 1442, owing to a reference to ironwork occurring in the chapter acts of that date. But on Canon Venables very kindly referring to the original, he found that it was not a reference to the erection of any ironwork, but to the removal of some. One almost identical is shown in an old view of Arras Cathedral, in the eighth volume of the "Annales Archeologiques," which secured the altar and reliquaries. The choir and eastern transept at Lincoln were built by a saint who died in 1200, and some division between these must have been required from the very outset, and there is nothing in the style of the grills to prevent us assigning them to this date. Canon Venables also informs me that there are screens in the Dome of the Rock at Jerusalem closing in a circular choir, of precisely similar character to those of Lincoln, which must have been erected during the reign of the crusading sovereigns of Jerusalem, when a "regular chapter of canons was established in this mosque," then converted into a Christian church and fitted up for Catholic worship.

The period when alone this was possible was between the taking of Jerusalem by the crusaders, in 1099, and its recapture by Saladin, in 1187. The design may have originated at Jerusalem, and been brought back by the crusaders, or it may have been suggested by something the smith or armorers had seen at home, and been adopted on account of the ease with which it could be made and its protective qualities. In either case, the date must be in the 12th or early in the 13th century. A similar, but decidedly later, grill, from Cravant, Yonne, is figured in the fourteenth volume of the "Annales Archeologiques," and ascribed to the 13th century.

The grill to St. Anselm's Chapel at Canterbury is of similar work, and exceedingly light, but differs in having the terminal volutes of the scrolls recurved, as in a crosier. There is another fragment of a grill of the same class in St. Alban's Abbey.

There is here a trial panel for a grill destined for the choir of Truro Cathedral, and designed by Mr. Pearson, R.A. The piece has been merely made to get the general effect, and has not faithfully reproduced his original, but it will do to illustrate the way such a grill can be produced. The upright bars are shaped in a very peculiar way at the top, and are narrowed and brought from round to square out of the solid, except the very apex, which is welded on. The cornice is of charcoal plate, and cut out with a chisel and riveted on. The small scrolls are formed by cutting bars of the right section into lengths, care being taken that there shall be a reasonable variation, so that there may be no mathematical regularity. The two ends are beaten out thin, and the whole scrolled up without heat. If the iron were thicker, it would have to be made hot, and the heated end would be allowed to droop over the round of the anvil, and a few gentle taps of the hammer would cause it to fall of itself into a graceful shape. They are bound together by small pieces of heated metal, or collars. The small pieces tucked in between them, intended to give little groups of dark points, arranged geometrically against the light, are more difficult to make, and require several welds each, and, moreover, must be brazed or pinned through in two places, to prevent them working loose under the collars. The whole aim and object is to invest the work with the character of 13th century work, and to avoid the extreme regularity and high finish which invariably betrays the modern reproduction.

The grills next described belong to an altogether different class, and here we have an example of absolutely known date in perfect preservation.

The grill to the tomb of Queen Eleanor was made by Thomas De Leghton for the sum of £12, besides 20s. extra for the carriage of the work, and his expenses and his assistants in London, during the fixing, A.D. 1294. The constructive part is simply a framework of two horizontal bars, connected by others at right angles, on the face of which is riveted scroll work of varied and exquisite design, and worked in much the same way as if it had been intended to be applied flat against wood work. It scarcely differs, indeed, from the hinge work of the same period, and is arranged in six panels, three of which are repeats The whole is arched over forward and surmounted by a cresting of speary tridents, a favorite form, for they recur on the chantry screen of William of Wickham, at Winchester, etc., and as far off as the Scaliger tombs at Verona. Though low, this grill would not be easy to climb. The grill to the tomb of Henry III., made by Henry of Lewes, and paid for in 1290, has disappeared, and the only other example of the same description of work is at the sister Abbey of St. Denis, and figured by Viollet le Duc.

Both these abbeys were extraordinarily rich in grills and railings. But in the French case they were swept away in 1794, when the brasses were melted and the stone effigies of kings shattered and piled up in fragments to form a fitting base to a statue of Liberty, and in England when, thirty years later, they were disposed of as old iron, because they impeded the view of the sculptures. In both cases a few seem to have escaped, chiefly because the intrinsic value of the old iron was small, and parts were stowed away as worthless lumber and forgotten. The grill to the tomb of Edward I., about twenty years later, as shown by Dart, is made up of little more than a few plain bars crossing each other at right angles, but it is just possible some handsomer work may have been applied to the face of it.

Nearly the whole of the ornamental part of these grills was produced by aid of stamps, or hollowed moulds of steel, which are impressed on the iron while heated and soft. These dies or stamps are made very simply. A leaf or flower of the desired form is forged in relief in steel, and this is driven into a larger block of steel shaped like a punch or wedge and heated to pasty condition, so that an intaglio is produced. Some dexterity is required in order to get sharp and clean impressions, as too sharp a blow from the hammer will

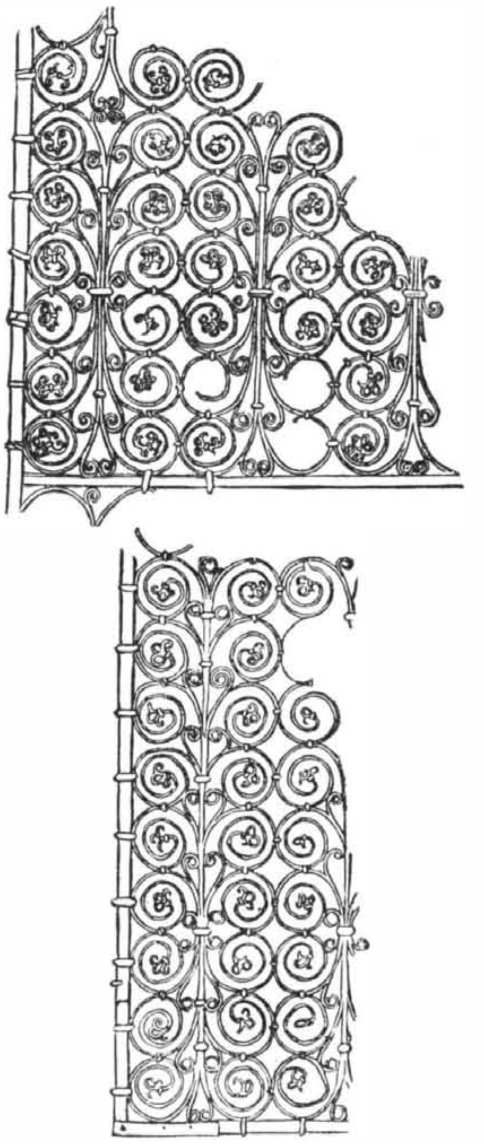


FIG. 4.—THE WINCHESTER GRILL; TWELFTH CENTURY WORK.

squeeze the metal out if hot, and if too cool the impression will of course be blurred and weak. I had some time since to make a stair rail, under Dr. Rowand Anderson, representing about this period of work, in which more than a mile of iron had to be decorated on both faces and scrolled up, the process requiring over 11,000 heats, exclusive of the welds.

All the grills hitherto described had one defect in common. Though excellent in construction and magnificent in appearance, they were not unclimbable. That this defect was fatal, considering the enormous value of the treasures they were designed to safeguard, is apparent from the variously devised *chevaux-de-frise*, and spiky crestings, and arching forms which were inherent features in them. Every device was exhausted in vain before the smith's repugnance to undertake the production of plain heavy bars was finally overcome. The manufacture of long unwieldy bars on an anvil was a laborious, and squaring the angles mathematically a difficult task, and on the whole, perhaps, thankless and monotonous; and very different from the production of the light and easily manageable scroll work they superseded. An imperative demand for strong and unclimbable grills carried all before it toward the second half of the 14th century, and the artisan of those days had need yield to it. Whether the tapering prongs of the trident cresting of the Eleanor type of grill, or the upright bars of this and of Edward I. grill, suggested the form commonly known as "railing," must, for the present, remain an open question, but there can be no doubt that it was arrived at by a natural process of evolution.

Henceforward, for a long time time, unless to fill in openings in masonry, protective grills were made up of vertical bars sufficiently massive to dispense with any cross ties, except at the top immediately under the cresting. These afforded no foothold, and afforded so efficient a protection as to remain in use during all suc-

ceeding ages. The vertical bars were generally an inch square, and ended in spikes, with a top rail wide enough for them to pass through. The angle uprights, and sometimes the central one, were also stouter, as much as two inches square, and higher, and were usually sur mounted with a crest of iron or carved wood. The horizontal bar was always more or less enriched on the face with plates of thinner metal embattled and pierced, and embossed to form a cornice, the work often being exceedingly elaborated, as if to show that the general simplicity was not the result of parsimony or incompetence.

One of the earliest of these is that of the Black Prince, at Canterbury, and there were innumerable and grand examples in Westminster Abbey, many with large heraldic devices at the angles. Often to give extra strength, and perhaps a lighter appearance as well, the bars were twisted, the resistance to any strain being thus thrown from the face only into the diagonal. At times this was effected by twisting several bars together. For the same reason the bars were generally placed angleways instead of square. It would be utterly impossible now to follow all the developments of this type of grill, but what strikes us forcibly at every step is that nothing was introduced at haphazard, or without a definite aim in view. The crestings became more elaborate, especially in France, where grinning dragons' heads thrust forward, with spike-like ears, *fleur-de-lis*, and clusters of spiny leaves took the place of simple spikes. The cornices occupied more space, and were more elaborate; tracery was inserted underneath between the bars, often of pierced sheet iron; the angle bars assumed architectural forms, with mouldings and buttresses, and the caps and bases of the vertical bars were also moulded. The file and chisel displaced the hammer and anvil, and instead of possessing the entirely distinctive character which its method of production demanded, and which it had maintained for many centuries, it was forced to assume, at a vast expenditure of labor, the forms that are proper to wood and stone. It was not till the time of Henry VIII. that grills in this country began to emancipate themselves from the purely architectural treatment, and Queen Elizabeth's tomb in the Abbey is almost the first instance of the introduction of a border of exquisitely natural roses into a tomb rail of iron. Thenceforward the railings rapidly branched out into Italian forms, and soon settled down into the groove so peculiar to England during the 17th and 18th centuries. The transitions preserved in our churches are of great interest, and also the instances where existing mediæval railings had been improved upon and modernized in the 17th century, as at York, etc.

That the vertical bar form was imposed from necessity, and not from choice, is abundantly apparent, as in cases where grills were required to entirely fill in openings in masonry—such as windows and arches—cross bars and other ornaments were introduced. The screen to the chantry of Henry V. at Westminster, and a similar grill at St. Albans, are examples where rich tracery designs could safely be substituted. The framework in these is exceedingly massive and difficult work, but a feeling of lightness is given by the introduction of much pierced sheet iron work. We cannot delay to explain the construction, but the result imparted a strength that would almost require artillery to force. This type seems very rare. Even in the case of tomb rails there was a tendency sometimes to make them lofty, and introduce more than one cross tie, and the bronze example round the Earl of Worcester's tomb at Windsor shows tracery between the bars carried a considerable way below the cornice; but the only example in this country, I believe, of a tomb rail in iron in which the precaution of at least a considerable space of vertical bars was absolutely thrown to the winds is that of the magnificent grill to Edward IV.'s tomb at Windsor.

The tomb is exceedingly plain, and perhaps it was thought that there was little to protect and something to conceal; but anyhow, the utmost skill of man seems to have been lavished on the grill in front. The work consists of six bays of tracery, about 5 feet 6 inches high, and two flanking half octagonal piers, 9 feet high. The brass grill of Henry VII.'s tomb gives an idea of the plan, but not of the intricacy of the work. It is in the richest style of perpendicular architecture, with traceried windows, canopies, parapets, crockets, flying buttresses, pinnacles, caps, mouldings, string courses, etc., complete. Scarcely an inch is plain, and the tracery is of all sizes, down to wire. A distinguishing feature is the magnificently worked cressets, or lanterns, surmounting the towers. The work has been attributed to Quentin Matsys, for no other reason than that it seems to have been impossible to suppose that any lesser artist could have executed it.

It is not in the least in the style, however, of the well cover at Antwerp, which seems the only work at all authentically attributed to Matsys, for the greater part of the one is as forged, while not a piece of the other remains in the state in which it left the anvil. It is also quite apparent that any middle aged man undertaking its execution would have been occupied for a large part of the rest of his life in tedious mechanical work that no artist of such caliber might have cared to settle down to. It is a singular thing that there should be no record concerning its production, and we are left to guess whether it is native or Flemish. The dearth of authentic information concerning the metal work in our cathedrals, with the single and notable exception of Westminster Abbey, and of course St. Paul's, is strange and, indeed, vexatious. The grill now occupies a meaningless position beside the altar, and should, in my judgment, be replaced in front of the royal tomb, of which it is an intrinsic and by far the finest part.

Another example of 16th century work unique in England, and also on that account attributed to a German origin, is the beautifully wrought gate in Ely Cathedral. This has much more in common with the work of Quentin Matsys, the filling in of the spandrels at the top and between the uprights being vigorous and natural, and, moreover, the genuine work of the smith. The dean informs me that tradition in fact assigns it to this master. The *repoussé* border is also delicate and good. Another exceptional grill of the 15th century is that restored in 1879 by Mr. Gordon Hills, at Chichester. The base of the grill formed what decorators call a "dado" of cross bars, with thin forged quatrefoils in the spaces; above this is a series of panels or windows, the design having been made out from fragments of the old work that had been used to patch the old gates to the Lady Chapel, and above this is a cornice and cresting. The old gates themselves are entirely made up of bars crossing each other with quatrefoils in the spaces. The value of such specimens cannot be overestimated, as they are the fountain head which must ever inspire English 15th and 16th century reproduction. Mr. Pugin revived the taste for mediæval metal work, but since then it has fallen into certain grooves, and repeats with monotonous regularity certain types of ornament for which there does not appear to be the least ancient authority. It is stiff and jerky, with impossible leaves ornamented with dots and zigzag lines, prim flowers, and twisted tube, and fretworks of stereotyped patterns. This kind of work is dying a natural death, however, and architects are more and more refusing to buy stereotyped designs, and infusing their own spirit into mediæval metal work. I am not able at the moment to exhibit any example of 15th and 16th century metal work. I may, perhaps, be permitted to illustrate its manufacture by means of a cartoon of a reading desk, recently executed from the design of Mr. Blomfield, and a memorial screen. With more notice, I might have obtained permission from Mr. Somers Clarke, its designer, to have retarded the latter, so as to have made use of it to-night, or I might have pushed on with one of the grills for St. Bartholomew the Great, designed by Mr. Aston Webb, and have shown that in a complete form. The construction of the reading desk is of necessity somewhat intricate, and we will pass on to the screen. The framing of this is very stout, the upright bars in all cases passing through the horizontals which bind them together. The twist is given cold, one end being firmly fixed, while the other is turned by sheer manual force. The spikes are hammered into form, and the buttress pieces to the central pier are roughly hammered into shape, and finished off with chisel and file. The bars are all tenoned and riveted together. The caps and bases of the pillars in the panels are entirely worked out by the file. The inscription is pierced with a minute bowstring keyhole saw, inserted into holes previously drilled. The buttress top is slit in the same manner, and the ends rolled down over a thin rod, which is afterward withdrawn. The leaves in the panels are hammered out of square rod, and welded on separately, and the roses are cut out of sheets of metal, and bumped up on the edge of a vise, and fixed on by brazing. The shields are embossed on a slab of pitch. The design is drawn on thin paper, and pasted on to the sheet of charcoal iron to be operated on, then pricked in in outline, the paper removed, and the relief gradually acquired by hammering with a small hammer on blunt punches of

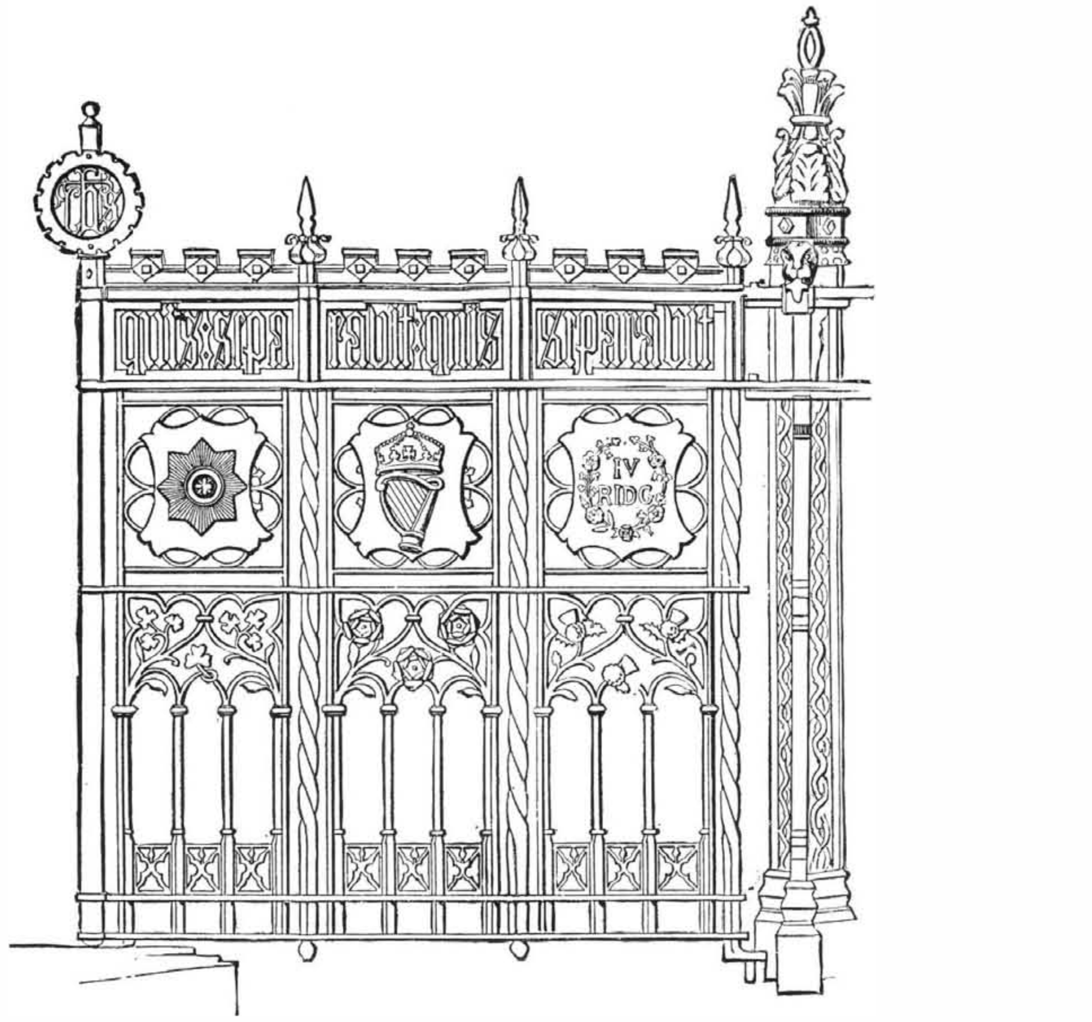


FIG. 5.—MEMORIAL SCREEN, DESIGNED BY MR. SOMERS CLARKE FOR THE FOURTH DRAGOON GUARDS.

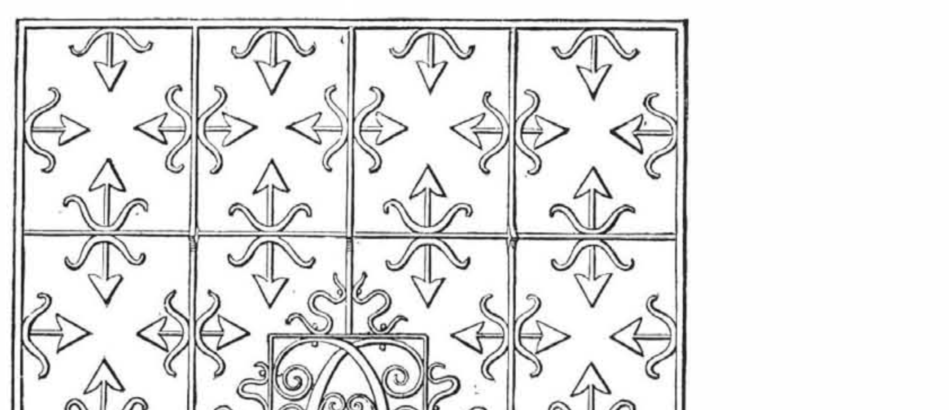


FIG. 6.—GRILL IN THE CONSTITUTIONAL CLUB, DESIGNED BY MR. R. W. EDIS, F.S.A.

various caliber. The hammering is required on both sides, and the pitch has to be remelted as often as the face of the iron is reversed. The dragon's head is roughly shaped when hot, a bar of iron being in the first place heated, and then jumped on the anvil and hammered up, until a sufficiently thick mass is formed at the end to allow of its production. The greater part of the production is, however, effected by actual chiseling and smoothing, as if carved from marble. The shields are fixed to the front, but the design at the back is so skillfully managed that they are not apparent, and it looks to be the real front. The design is very original, and yet so characteristic that it might pass for old work were it not for the blazons of the Royal Irish Dragoon Guards, who erected it. But to judge of its merit it should be seen complete, with the stone and bronze work of the rest of the memorial, when the reasons for its proportions become apparent.

Comparatively little was made of iron in the Tudor and Jacobean styles of architecture. Bolts, locks, hinges, etc., are of plain character, though serviceable and quaint. The railings round the tombs of Mary Queen of Scots and Elizabeth have disappeared, but good representations show the former to have differed but little from earlier 16th century examples, and the latter have been described. The universal use of stone walls and balustrades outside, and carved oak within, reduced the smith's art to a low ebb, and it was not till the accession of William III. that the art blazed out again in sudden splendor. The armorers with their traditions must have been available for the revived art, but wherever the workmen came from, there was no lack of skill when Tijou, a Frenchman, in 1693 published a book of designs for smiths' use, among which appeared the celebrated screens commanded a little later by the king for Hampton Court, and which were actually executed by Huntingdon Shaw. This work, and that in St. Paul's, had very much in common with the French work of the same period, but toward the beginning of the 18th century our English work diverged more and more, and assumed that peculiar mannerism which is its distinctive character, and which is called Queen Anne or Georgian. The finest examples of the earlier style are, as already mentioned, at Hampton Court and St. Paul's, and there is another fine one at 45 Lincoln's Inn Fields, admirably described by Mr. George H. Birch. The French work diverged more and more, and set a fashion in southwest Germany, which perhaps culminated at Wurzburg, while an approximation to the English style prevailed in the North. The art had also survived in France while it was dormant here under the Stuarts, and in a fashion that has no counterpart in this country. A staircase designed by Dr. Rowand Anderson, for the Central Hotel at Glasgow, has admirably caught the feeling of Henri II., and consists of pleasant alternations of light and shade, and of strength and delicacy. I am also permitted, by the kindness of Messrs. Jackson, to exhibit a panel from a very handsome stair rail of Louis XVI. style, of polished iron, the construction of which would be of interest did time permit a detailed explanation. Of the same work is a large basket-shaped chandelier and a lantern, designed by Mr. Edis for the grand staircase of Chesterfield House, where there is a fine original stair rail of wrought iron, apparently French in design, if not execution, and of the time of Louis XV. The same architect designed the very quaint and exceedingly protective grill which I have photographed from the front of the Constitutional Club. There is an intensely *noli me tangere* look about it, without any loss of decorative effect, and it seems altogether so happy that, though of foreign style, I have reproduced it. The large gates, by Mr. Sydney Mitchell, like those recently executed for the South Kensington Museum by Mr. Taylor, architect to the office of works, are not founded upon any particular models, but seem admirably designed for the buildings that receive them; but the large gates exhibited, which were designed for Gordon College, Aberdeen, by Mr. Marshall Mackenzie, are more distinctive of the English 18th century work, good examples of which are to be seen in every suburb of London, and scattered over the country.

Perhaps on a future occasion I may, if desired, go more deeply into the 17th and 18th century work, which deserves at least an entire evening. I cannot conclude without expressing my thanks particularly to three men from whose hints and instructions at an early period of my career I was able to gather almost all I have told you to-night. These are Mr. L. Karslake, Mr. W. Unsworth, and Mr. G. H. Birch, whose support, with that of Messrs. Ernest George and Peto, Dr. Rowand Anderson, and Mr. C. Baker King, enabled me to found a factory, and in some respects a training school, which has not, I trust, proved altogether useless, and by which I believe many engaged in the same manufacture have more or less directly profited. I do not of course allude to those old established firms who were pioneers when smithing as a fine art did not exist, but to those who have entered the business in my own time, and who seem to think it more easy to learn from their neighbors than direct from the older examples, which are common property to all alike.

A series of drawings of English historical iron work, by Mr. O. Allbrow, was kindly lent for exhibition by the science and art department.

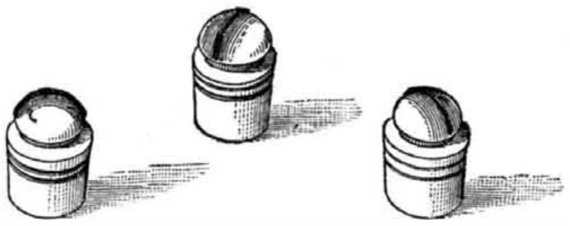
CAUSES AND PREVENTION OF STOPPAGE IN BURNER TIPS.

MR EUGENE PRINTZ, of Zanesville, says the complaints came mostly from persons using the low or night lights. On those burners the crystals were deposited, on either side of the slot, on the tip, in a fringe-like mass, as per the sample we have here for your inspection. The explanation of this we would think to be that, the light being down low, the requisite temperature of the clay tip for the decomposition of the bisulphide was not reached until the gas was just passing from the opening, and then the deposit was made on the outside. We did have some complaint from burners that were expected to be burned at a full head, but think the bisulphide theory will hold good, and can be accounted for in this manner.

When the lights are burning full, the necessary temperature to decompose the gas is raised further down, or inside the tip, and there the carbon crystals are formed and deposited; then may be broken or detached and carried on by the flow of gas to the slot. Being very small, should they enter the slot lengthwise they pass on and are consumed in the flame; but on the other hand, should they strike crosswise they are apt to remain, causing a division in the jet of light, and finally, by their increase in number, require the use of a burner cleaner, or a complete stoppage of the gas is the result.

We have here, then, not only a cause for the stoppage of the burners, but a reason for the sulphur fumes that are complained of at times. The carbon of the bisulphide being deposited, the sulphur unites with hydrogen to pass through or from the burners as the sulphide of hydrogen.

Looking at the matter in this light, is it not probable that many of us do not appreciate the importance of the bisulphide of carbon as an impurity, and should we not be better prepared for its elimination? To be sure, we expect the ammonia in the washers, as sulphide of ammonium, or the lime in purifiers, as the

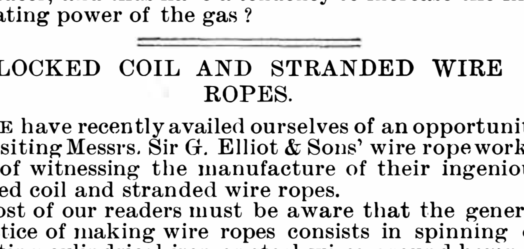


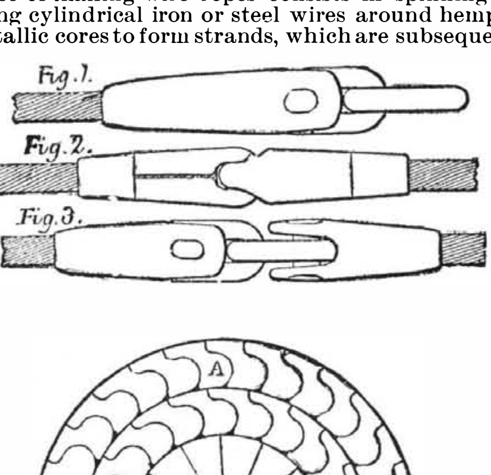
sulphide of calcium, to perform this duty; but as these do often fail, and as a precaution, then, would it not be well for us in some manner to take out or decompose the bisulphide before the gas enters the lime or oxide of iron purifiers, giving them only the sulphide of hydrogen to deal with? As a suggestion, let the gas be passed through an iron retort filled with a loose clay material, heated to about 500° temperature by utilizing the waste heat from the furnaces. This should be done after all the tar has been extracted, otherwise the clay material would soon be choked. It may be possible that the watery vapors would be decomposed; but would this be a disadvantage? Is it not likely in this case, there would be a recombination of the hydrogen with carbon and sulphur dropped as free sulphur? or possibly a monoxide of carbon would form, which, while not a light producer of itself, might be useful as a heat producer, and thus have a tendency to increase the illuminating power of the gas?

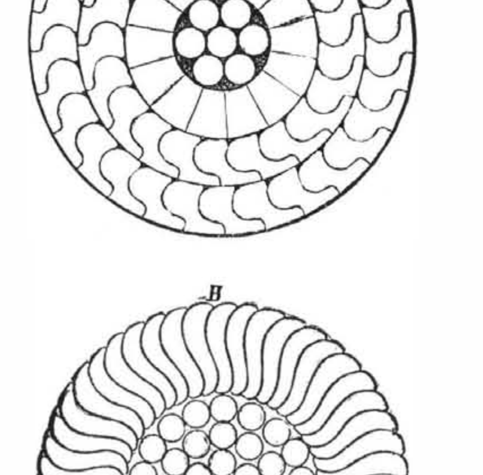
LOCKED COIL AND STRANDED WIRE ROPES.

WE have recently availed ourselves of an opportunity of visiting Messrs. Sir G. Elliot & Sons' wire rope works, and of witnessing the manufacture of their ingenious locked coil and stranded wire ropes.

Most of our readers must be aware that the general practice of making wire ropes consists in spinning or twisting cylindrical iron or steel wires around hempen or metallic cores to form strands, which are subsequent-







ly similarly twisted or closed around a central heart, thus forming the completed rope. The manufacture, in fact, is very similar to the old process of spinning hemp cordage. Upon examining the construction of such a wire rope, it will be seen that while the cores serve as supports upon which the wires and strands are laid in position, they do not add tensile strength to the rope. This will be apparent when it is remembered that the outside wires of the strands and the strands themselves are, owing to their varying circumferential turns, necessarily longer than the cores. It is also obvious that the open structure of the ordinary rope leaves interstices for absorbing water and dirt, while the external configuration causes uneven and severe local wear at the crowns of the strands.

The system introduced by Sir George Elliot & Sons, and which we are about to describe, presents several features of novelty and interest. The rope is composed of specially shaped wires, so formed that when closed together they interlock, and thus while reducing the defects before mentioned, present a structure with a more uniform wearing surface, and in which each wire is firmly locked in its proper position.

This ingenious arrangement was introduced in 1884, and some samples were shown at the Inventions Exhibition the following year. At the present date it would be premature to express any definite opinion as to the probable ultimate value of the invention. The ropes in practical use are, however, doing well, and the rest remains for time to prove.

The manufacturers produce two distinct types of ropes, viz., the "locked coil" and the "lock stranded" ropes, the former of which are illustrated in the accompanying diagrams, where A represents a transverse section taken through one of the "locked coil ropes," composed of a simple wire core, around which are laid a series of radial wires and two layers of locking wires of special form as indicated in the illustration. In the second example, B, the section represents a locked coil rope, composed of a compound wire heart, around which a suitable number of radial locking wires are closed. The manner in which the "locking" of the external wires is effected in both examples appears to require no further explanation, as the arrangement is clearly shown in the diagrams.

It will be evident that in this manner a dense and compact metallic rope is formed, with an external surface composed of wires locked in position and presenting a uniform and smooth wearing surface, like a round bar or rod. These ropes are highly flexible, and should any wires become broken they will still continue to lie in their normal positions, whereas, in the ordinary construction of wire ropes, broken wires commonly turn outward, thus causing obstructions and wear, and sometimes stripping of strands. The idea is unquestionably useful and ingenious, but, although advantages in its favor are apparent, nothing can thoroughly demonstrate its true value but severe and prolonged use.

It is, however, such a wide departure from the present recognized practice of wire rope making, that some difficulties will probably attend its extensive employment. The first cost of the ropes is at present higher than those of the ordinary construction, but this should not be an important objection if the ropes prove more durable. It is not pretended that the "lock coil rope" is capable of being spliced, but there exists a wide demand for unspliced ropes, and "socketing" is now frequently adopted as a means of connecting ropes which are even capable of being spliced. For example, in colliery endless haulage systems, the ropes are sometimes united by sockets instead of by splicing, as a quicker and more economical method; while for winding ropes and main or tail rope haulage, splicing is not necessary.

This method of connecting the ropes is represented in Figs. 1, 2, and 3, which show a suitable arrangement of winding or tail end socket, and two types of coupling sockets respectively, the ends of the ropes being plugged, brazed, or wedged therein, as may be convenient.

In cases where it is found advisable to adopt a rope which may be spliced, the "lock principle" is modified into what is known as a "locked stranded rope," and which practically consists in forming a rope of the ordinary type, composed of locked wires. This rope is capable of being spliced in the usual manner.

The manufacture of the "locked coil rope" is effected in one operation, while in the practice of ordinary rope making two separate operations are involved, *i. e.*, strand forming and rope closing. The Elliot type is "closed" direct from one set of bobbins into the finished rope, the machinery employed for the purpose being very ingenious and effectual.

Although we have selected only two sections of lock ropes and wires for illustration, it will be understood that numerous types of sectional wires may be employed with similar results. The advantages claimed for the system are as follows:

With ropes constructed according to this system, there results great durability, as the inside layers, which furnish half the strength of the rope, are not exposed to wear. The wearing surface is quite uniform, and its smoothness reduces the friction to a minimum. The ropes are perfectly flexible, and as they have no hemp within them, there is no tendency to corrosion. The wires are securely locked in their places, and all bear an equal strain. Hence the strength of the rope is greater than with the usual construction, and there is no tendency to spin.

The efficiency and strength of these ropes as compared with others of ordinary construction appears well demonstrated by the following data obtained from Lloyd's testing house at Cardiff. A crucible steel wire "lock rope," 2·18 in. in circumference, gave an ultimate tensile breaking strain of 101·7 per cent. of the aggregate breaking strains of the wires contained and previously tested. An aggregate efficiency of from 85 to 90 per cent. of the actual breaking strains of the separate component wires is the usual average results in ropes of ordinary construction. The breaking strain of the Elliot rope was 21 tons, whereas an ordinary wire rope of the same circumference would only stand about 13 tons before breaking. Further, the weight of the lock rope was 6 lb. per fathom, whereas an ordinary rope of equal strength weighs about 8 lb. per fathom.

Referring to some practical applications of the ropes which we have had an opportunity of inspecting, the following particulars will be found of interest. At the Kimblesworth Colliery, Durham, a crucible steel locked coil winding rope, 45 fathoms long and 2¾ in. in circumference, has been raising about 500 tons of coal per day for the past ten weeks under severe conditions. The lift is effected in about 10 seconds, the overhead pulleys are only 9 ft. in diameter, and the winding drum is of the same size, yet at present the rope exhibits no signs of wear or elongation. The position and work of the rope was admitted to be severe, and we are informed that the usual life of an ordinary rope similarly employed is from eight to twelve months. At the same colliery we inspected an underground main and tail rope system of haulage, in which a locked coil rope has been running in satisfactory daily operation for about

a year, and shows no appreciable signs of wear. The rope thus employed is about 1,100 yards in length and $2\frac{1}{4}$ in. in circumference, the speed of hauling being about ten miles per hour. The rope worked very silently over the pulleys, and was worn smooth and bright like a polished rod.

At the Pelton gravitation incline, Durham, about 900 yards in length, we examined a "locked stranded" rope which has been continuously working for the past thirteen months, and yet shows no external signs of depreciation; 800 tons of coal are let down this incline daily This is a surface incline, so that the ropes used upon it are fully exposed to all kinds of weather.

At the Holmside Colliery, Durham, we inspected a (S or under) locked coil winding rope, which had been working successfully for the past nine months. This rope is $2\frac{3}{4}$ in. in circumference and 132 fathoms in length. It appears from inspection to be practically as good as when new.

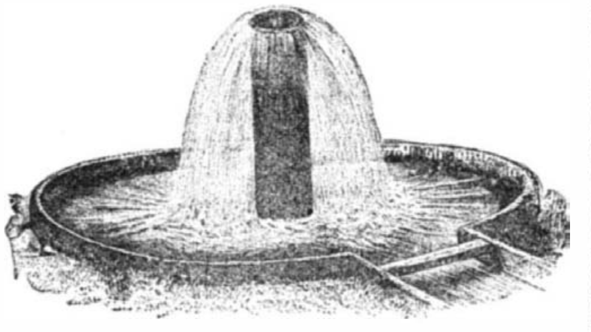
At the Hilda Colliery, South Shields, we examined a small underground winding rope, $2\frac{1}{4}$ in. in circumference, which has been in daily operation for about thirteen months, in a position said to be very trying, owing to repeated severe deflections and bending around a $3\frac{1}{2}$ ft. winch barrel, etc.

At the Boldon Colliery, near Tyne Docks, an underground locked coil haulage rope, 2 in. in circumference, is working round a sharp curve and on an incline of 1 in 3, at the bottom of which the sets had to be promptly detached or the rope was seriously jerked. This is unquestionably a severe test position. The rope has, however, now been at work for about six months, hauling some 800 tons of coal per day with every satisfaction. It was stated that previous ropes used in the same place and of the common construction only lasted about half the time this rope has already run. The length of this rope is 150 yards, and the speed of haulage about ten miles per hour.

We are informed that a locked coil winding rope $2\frac{7}{8}$ in. in circumference and 370 yards long has been working for the pass fourteen months at the Powell Duffryn Colliery, Aberdare, during which time it has only reduced $\frac{1}{32}$ in. in circumference, which is considered a remarkable result after such a period of work. Similar cables have recently been supplied to the Bridgewater Trustees, near Manchester, of $4\frac{7}{16}$ in. in circumference and 760 yards in length.—*Engineering.*

THE STEAM YACHT CHEMCHECK.

THE engravings illustrate the steam yacht Chemcheck, and her engines, built by Messrs. Miller, Tupp & Rouse, Hammersmith, for cruising in the Bosphorus and Mediterranean. She is a fine, handsome, commodious yacht, 65 ft. in length, 12 ft. beam, with a depth of 6 ft. 6 in. and 5 ft. aft. She is carvel built of teak throughout, and is copper fastened and copper sheathed. The stem, stern post, and transoms are of English oak, and the keel timbers and stringers of American elm. She is decked fore and aft with $2\frac{1}{8}$ in. yellow pine. The main cabin is forward, handsomely paneled in teak, and with teak skylight and companion. Ladies' cabin abaft the engine room, with two berths, paneled in teak; lavatory and other fittings. A bulwark, 15 in. in height, is fitted round the vessel, with galvanized stanchions and rails. The engines are compound surface condensing, with cylinders $9\frac{1}{2}$ in. and 17 in., by $9\frac{1}{2}$ in. stroke, and are fitted with Messrs. Miller,



ARTESIAN WELL, OUED RIR'.

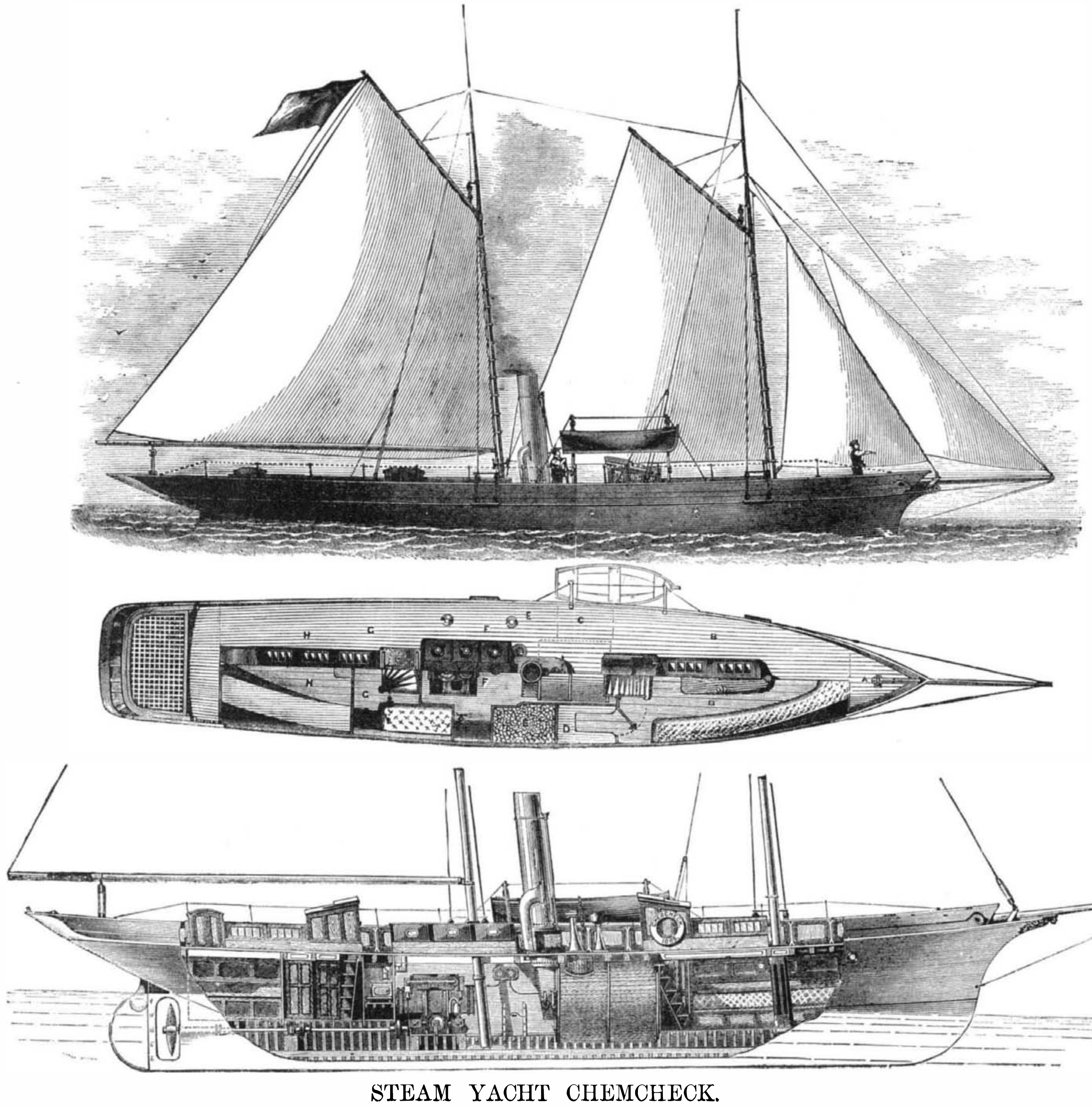
Tupp & Rouse's patent valve reversing gear. The air and circulating pumps are driven by an independent engine, fixed on the main engine bed plate. The boiler is of the marine return tube type, 5 ft. diameter and 7 ft. long, with forty-six $2\frac{1}{2}$ in. tubes, working at 80 lb. pressure, and is fitted with a Dolphin donkey pump in addition to the engine feed pump. The propeller is of gun metal, 48 in. diameter and 6 ft. pitch, making 200 revolutions per minute. The screw shaft is $3\frac{1}{4}$ in. diameter, and is bushed with lignumvitæ in the stern tube. The yacht is schooner rigged, and has a 12 ft. mahogany whale boat and a 12 ft. dingey hung at the davits. On her official trial by Captain Comyn, she ran 10·55 miles an hour on an average of four runs, the builder's calculations being based on a speed of $10\frac{1}{2}$ miles an hour. The Chemcheck steamed out to Constantinople with a crew of runners, and behaved exceedingly well in a heavy gale in the Bay of Biscay. —*The Engineer.*

THE ARTESIAN WELLS OF THE OUED RIR'.

THE immense basin of alluvium of the Chott Melrir, or of the lower Tunisian and Algerian Sahara, is, at the same time, a remarkable artesian one. We shall here briefly give the principal conclusions of the observations and studies that have been pursued by us for six years in regard to the nature of the artesian water of this basin, and particularly that of the Oued Rir'.

The Oued Rir' is a wide valley, which descends from the south to the north for 78 miles, and ends to the southwest of the Chott Melrir. Upon its eastern edge, it presents a narrow zone of flat land. Here there is a subterranean reservoir of water, along which extend numerous wells, sunk either by the natives or by French augers, and discharging, altogether, about 140 cubic feet of water per second, at a mean temperature of 25 degrees. The water-bearing stratum is situated amid permeable sands belonging to our lower drift, and is covered with a marly and impenetrable mass of earth of our lacustrine formation, which is 210 feet thick, and which keeps the water under pressure. In places, this water has been enabled to effect a passage for itself to the surface, giving rise to natural springs, *behour* and *chria.*

From the remarkable works of the inspector-general of the Ville mines on the artesian water of the Sahara, we know that it is not here a question of one or several ordinary sheets of water, regular and concentric with the geological strata and comparable in length and width. There is one main sheet, which, when the covering is imperfect, is at times accompanied with two lenticular ones above. This sheet exhibits its maximum pressure and volume on the east side of the valley, but disappears quite abruptly toward the west, although the marlo-lacustrine formation extends beyond. It is a north by south elongated aquiferous zone, limited at the sides and coinciding with one of greater permeability of the lower sands. It is a sort of subterranean artery. Its bearings are capricious, and it required all the experience and sagacity of Mr. Jus, director of the borings, to determine them. This artery meanders under cover from Ourir at the north as far as to Tougourt at the south, a distance of 60 miles. Its known width varies between $2\frac{1}{2}$ and $8\frac{1}{2}$ miles. At the center of the Oued Rir', opposite Ourlana, it divides toward the north, and doubtless also toward the south, so as to form an irregular X. The ascensional force and the discharge of the wells is very variable, even along the artesian zone. The two chief factors, all things being equal as to the subterranean conditions of supply, are the permeability of the aquiferous sands and the impermeability of the cover-



STEAM YACHT CHEMCHECK.

ing. As for altitude, that has little influence upon the pressure, the artesian water doubtless having feed reservoirs situated above it.

An analogous, but smaller, artesian zone exists 60 miles further to the south, under the plateau of Negoussa at Onargla (525 feet altitude). The total discharge of the spouting wells of this region is about 35 cubic feet per second, at a temperature of 24°. The covering of the artesian water consists of a stratum of clay.

In addition, there is a general diffusion of artesian water in the sandy soil of the lower Sahara, to the north of which have been found some ascending or feebly spouting sheets. Through the entire basin there exists an ascending sheet, which, through pressure and capillarity, rises to the surface, follows the undulations of the soil, and, flowing through the depressions, feeds the *sebkhas* and *chotts*. It is this that filters to the bottom of the natural funnels of the Ain Taiba, of the behar Ramada, etc., into the ordinary wells, the excavations of the souf, and the feggara of the Nefzoua.

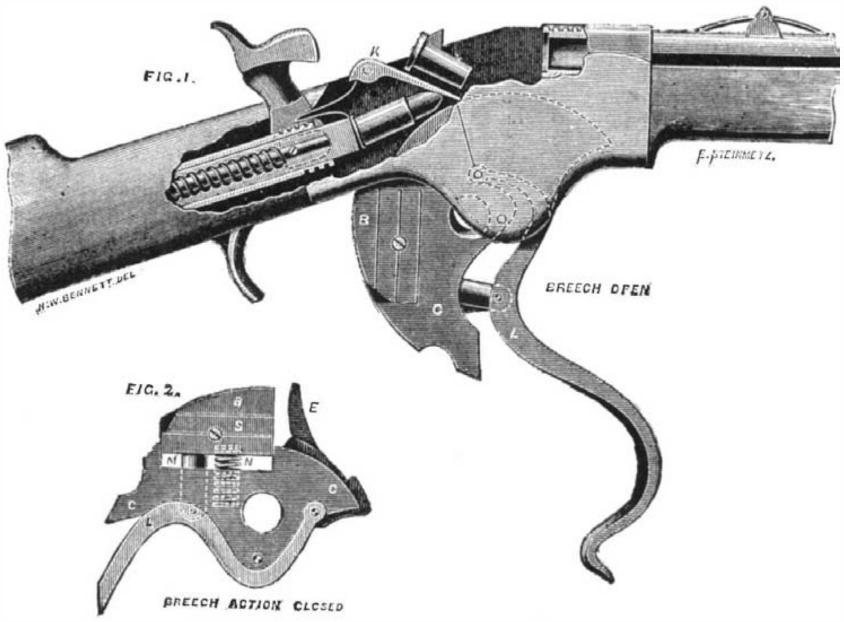
In the climate of the Sahara, an active evaporation everywhere takes place at the expense of this upper sheet, and is incomparably greater than the discharge from all the spouting wells of the Oued Rir' and of Onargla.

Whence and how are the artesian strata of the basin under consideration fed? In the first place, by rain water and the influx of rivers, especially of those that rise in the Atlas to the north, and that are subject to an annual overflow. These waters partially infilter into rise all around, with slight dips into the Sahara, so as to form an asymmetrical and still vaster reservoir. Water circulates therein in variable quantity. It is abundant in the mountains of the north, whence a portion runs toward the south, and it is not wanting even upon the cretaceous plateaux of the Sahara, as is proved in the high Algerian Sahara by the numerous wells of the *chebkas* of the Mzab and the south, the subterranean water-courses of the plateau of Bou Noura, and, in Tripolitania, by the cretaceous springs of Ghadames. Now, as the cretaceous water tends to collect at the bottom of the reservoir, it must form therein artesian sheets or zones under a high pressure that spout through certain lines of fracture in the strata and then rise and distribute themselves in the superposed alluvium. These phenomena of subterranean springs seem to us especially probable toward the north of the basin and at the base of the western slope of the reservoir, where they are more or less directly connected with the artesian arteries of the Oued Rir' and Onargla.—*G. Rolland, in Le Genie Civil.*

MAGAZINE RIFLES.

In view of the efforts now being made by all the chief military powers to obtain the best type of magazine rifle, it may not be inopportune to put before our readers a brief sketch of the past and present history of this description of arm. As most of them are probably aware, the "repeating" or "magazine" rifle is, relatively speaking, not a new invention. It was employed nition as would require very large reserves to sustain the fire, also that the soldier would be led to undervalue the power of each individual round. However, it will be remembered that precisely similar objections were made to the introduction of breechloading small arms, and the leading military powers have now accepted the principle that the adoption of a magazine rifle is not only advisable but absolutely essential, in view of the fact that the possession of a weapon able to fire a certain number of rounds in very rapid succession at the critical moment of an attack—and more especially of a defense—might decide the fate of an action. Considerable stress is also laid on the moral effect of being in a position to pour such a rain of bullets upon an enemy. On the other hand, it has been shown by experiment that, up to the present time, a single loader of the simplest construction will fire a considerable number of rounds as rapidly, if not more so, than a magazine rifle. This arises from the necessity of pausing to refill the magazine. But the delay due to this cause can probably be greatly reduced by using interchangeable detachable magazines, or by inserting into a fixed magazine at one motion a number of cartridges in a very light metal frame.

For some years past, both in Europe and America, mechanical ingenuity has been exercised in simplifying and perfecting models of magazine rifles, with the object of producing an arm which shall be simple in mechanism, not liable to get out of order when in active service in the field, available for use as a single loader, and of moderate weight. The different descrip-



THE SPENCER MAGAZINE GUN.

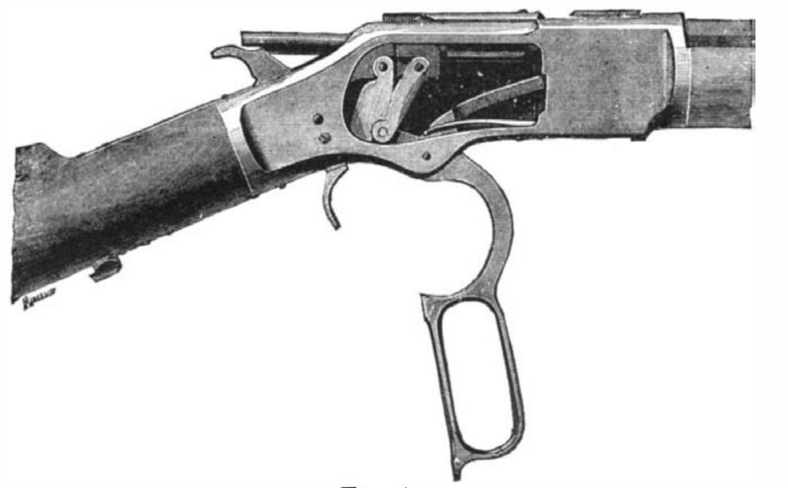


FIG. 4.

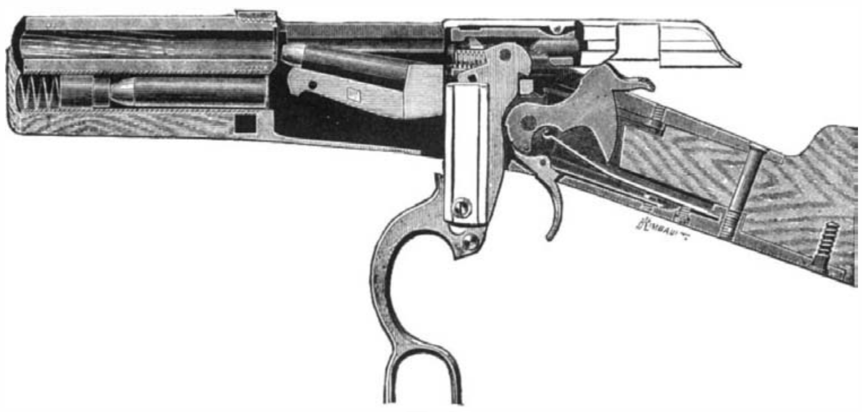


FIG. 5.

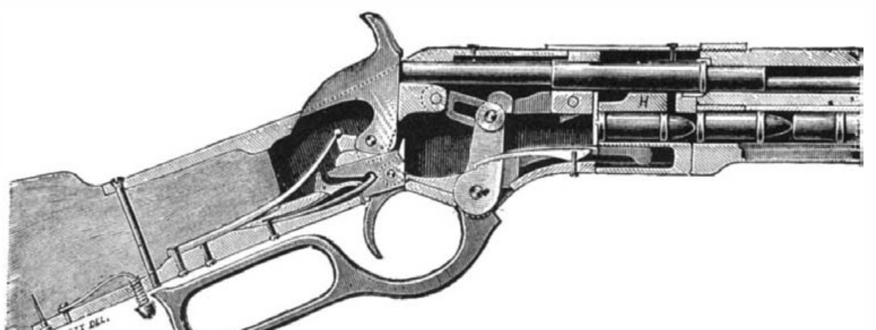


FIG. 3.

THE WINCHESTER MAGAZINE GUN.

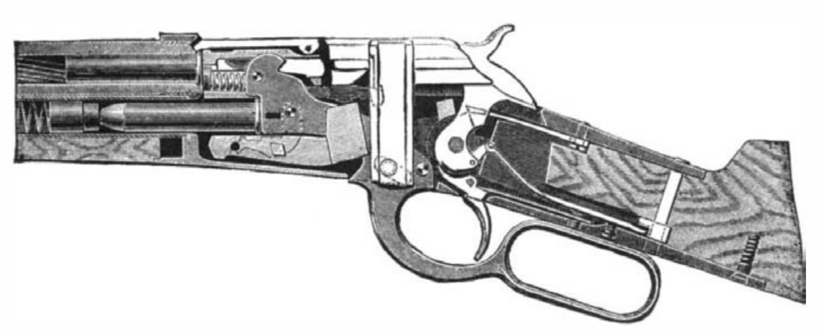


FIG. 6.

THE WINCHESTER MAGAZINE GUN, MODEL 1886.

the permeable soil, and then descend and distribute themselves through the alluvial formation, which runs toward the interior of the basin, and the arrangements of which lead them to be ascending or spouting in the low regions.

On another hand, the cretaceous earth of the mountains that stand at the north contains strata of water fed by the rains and snows that fall upon these masses (whose height reaches 8,000 feet in the Aures), and these waters, on flowing toward the south, give rise, along the northern extremity of the lower Sahara, to the beautiful springs of the eastern and central Zab described by Ville, and, on the east, to the analogous springs of the Djerid. Mr. Jus has observed that the water of the cretaceous springs of the western Zab disappear in the alluvium, and form little rivers, which descend toward the south. These become grouped beyond, and a main river, flowing southeast-south, becomes in the lower sand a great river situated to the southwest of the Chott Melrir, under the marlo-lacustrine formation, whence the compressed waters are afterward forced into the artery rising under the Oued Rir' to the south. Further to the west, another river descends directly toward the center of the Oued Rir'. Moreover, to the springs that come to the surface of the Zab are to be added other cretaceous (but subterranean) ones, which spread out at various permeable levels of the alluvium.

We think that similar springs exist in other regions of the northern extremity and even of the interior of the basin. It is well known that the cretaceous strata extend without break under the alluvial basin and in two or more of its earlier forms during the American civil war, and was also used to a certain extent in the struggle of the Turks against the Russians in the Balkan provinces.

The above terms are now employed indiscriminately for any rifle which can fire a number of rounds in succession without loading afresh, but the name "repeating" was originally and more correctly applied to an arm identical in principle with the ordinary revolver pistol, in which the cartridges are at once loaded into a number of separate powder chambers contained in a cylinder revolving on a central pivot. It has been found by experience that, with the heavy charges now fired from a military rifle, the escape of gas at the joint between the revolving chambers and the fixed barrel is so great as to render this construction unsuitable, in addition to the excessive weight of such an arm, and the difficulty of extracting the empty cartridge cases. It has therefore been given up even by Colt, the first inventor, in favor of a "magazine" properly so called, which we may define as a receptacle for containing a number of rounds of ammunition, which are successively fed into the cartridge chamber of the rifle, and are therefore fired under precisely the same conditions as if the weapon had been loaded by hand each time.

It may be premised that the best military authorities have been and are still much divided as to the practical utility in the field of magazine arms. In addition to the objection naturally arising from their more complicated construction as compared with single loaders, it has been urged that their general adoption would probably lead to such a wasteful expenditure of ammu-tions may be classified as follows, keeping to our definition of a "magazine" rifle:

1. Those in which the cartridges are placed in a tube underneath the barrel, in connection with the fore end of the stock, such as the Winchester, Vetterli, Kropatschek, and Mauser magazine rifles. The chief objection to this plan is that the balance of the weapon is constantly altered, as the magazine is being emptied. There is also the possible danger of the explosion of a charge in the magazine from a percussion cap projecting or being oversensitive, since the base of each cartridge rests against the point of the one next in front of it.

2. Rifles in which the magazine is contained in a tube inserted in the butt of the stock, as the Spencer, Hotchkiss, Chaffee-Reece, Maxim, etc. In this case the balance of the rifle is not so greatly affected by the emptying of the magazine, although the objection remains of the apex of one cartridge resting against the base of the next. It is, however, evident that a tube in the butt cannot contain so many cartridges as one underneath the barrel.

3. "Central magazine" arms, in which the magazine is just in rear of the cartridge chamber of the barrel, its shape and precise arrangement differing considerably in the various models.

The advantages of the central magazine are (i.) that the balance of the rifle is not in the least affected by the varying number of charges in the receptacle, (ii.) that there is no danger of premature explosion from a projecting or oversensitive percussion cap, and (iii.) that the cartridges can be far more easily inserted in

the magazine than in either the first or second forms. This class may conveniently be subdivided into:

(*a.*) Drum or horseshoe magazines, as in the Schulhof, which is the best representative of this division.

(*b.*) Box form, inserted underneath the shoe in a slot just in front of the trigger guard. This is the Lee magazine. But the Spencer-Lee, the Pieri, and the Austrian Mannlicher have a similar form.

(*c.*) Box form, placed above or on one side of the shoe. The original Jarman, the Burton, Lee-Burton, and Owen-Jones have this form, which has the merit of dispensing with the magazine feed spring, since the cartridges fall successively into the position for loading through the action of gravity alone. This kind of magazine is, however, much in the soldier's way, and is bad for aiming. In the Morris rifle, six cartridges are contained in a light skeleton frame, which fits on top of a receptacle on the left side of shoe, and which can be thrown away when empty. Nine cartridges in all can be contained in the rifle, viz., one in the chamber, one in the shoe, one in the receptacle, and six in the frame.

In addition to the above classes of magazines, which are all self-loading, certain appliances, termed "quick loaders," have been devised, which can be attached to ordinary single loader breechloading rifles. These are mostly in the nature of the box magazine, and present each cartridge in turn in a position to be rapidly fed into the chamber by hand. These quick loaders are evidently inferior in every respect to detachable magazines, and are even more in the soldier's way.

Spencer Rifle (see Figs. 1 and 2).—This was about the earliest magazine rifle, and the first tested by use in actual warfare, having been patented at Boston, United States, so far back as 1860. It comes under the second class, the magazine being contained in a tube in the butt. It held seven cartridges, which fed up to the breech action by means of a spiral spring, each being successively guided by the flat conductor, K, made to press downward by means of a spring. In the original model the breech was closed by a revolving block in two pieces, B the block proper, and, C, the central piece, which latter was hinged or pivoted to the under part of the shoe or body. When the lever, L, connected with the block by means of the cylindrical bolt, M, and which also forms the trigger guard, is pressed downward to the front, the "block" slides into a recess in the central piece (see Fig. 2), the latter rotating and leaving the chamber open. This motion, likewise, causes the movable extractor, E—attached to the left side of the center piece—to withdraw the empty cartridge case, which is deposited on the upper side of the conductor, K, while, at the same time, a fresh cartridge is fed up from the magazine, and held between the conductor and the block.

On again raising the lever, the block catches the fresh cartridge and forces it into the chamber, when the block rises by the action of the spiral spring, N, and completely closes the breech. This upward movement also causes the conductor sharply to eject the empty case.

A new model of the Spencer, so altered as to be quite a different arm, will be noticed in its place; also the Spencer-Lee, which has the new Spencer breech block combined with the Lee central magazine.

Winchester Rifle (Fig. 3).—This weapon, probably the best known of the early repeating rifles, was an improvement on the "Henry," by the Winchester Arms Company, whose name was then given to it. The Henry was used with considerable effect during the American civil war. The Turkish calvary, in the Russo-Turkish war, were armed with the Winchester, and it was also used by some of the Turkish infantry at Plevna. It is the first representative of Class I., in which the magazine is placed underneath the barrel, the cartridges being fed toward the breech by a spiral spring. The magazine can hold fifteen rim-fire cartridges, and is filled through an aperture at the right side of the shoe or body, which is closed by an automatic spring cover.

The cartridge next for use is pressed by means of the spiral "feed" spring into a carrier or hopper in line with the magazine tube. This carrier is actuated by the lever forming the trigger guard. The motion of lowering this lever ejects the empty cartridge case, cocks the rifle, and raises the fresh cartridge in the carrier to the level of the barrel. On returning the lever to its original position, the carrier is lowered, the cartridge pressed home into the chamber, and the gun ready to be fired.

Winchester Repeating Rifle, New Model, 1886 (Figs. 4 to 6).—This arm, which has much the same external appearance and is manipulated in the same manner as the earlier patterns, yet possesses several distinctive features. These improvements are, taking them in the order of importance:

1. A most effective locking arrangement, which adds great strength to the breechloading mechanism, and allows of the heaviest military charges being fired from the rifle. Two locking bolts (left unshaded in the sections, Figs. 5 and 6) have a vertical motion communicated to them by means of studs which work in a slotted groove in the hand lever; when the action is closed, the bolts slide up into corresponding slots in the breech bolt, one on either side of the firing pin or striker, thus securely locking the bolt. The tops of these safety bolts are visible in the drawing (Fig. 4) of the exterior of the rifle.

2. The hand lever has a shorter radius, giving a less movement than in the older models, thus allowing the rifle to be manipulated with ease when at the shoulder.

3. A hook, attached to the lever, assists in withdrawing the cartridge from the magazine into the carrier. This permits of the magazine spring being comparatively weak, so that the magazine can be filled with ease.

The action of the rifle will be readily understood with the aid of the illustrations. The very first downward movement of the lever withdraws the firing pin within the front face of the breech block, and locks it back until the arm is again ready for firing, while the empty cartridge case is extracted from the chamber and ejected. At the same time the elevator or carrier raises the fresh cartridge to the level of the bore, and the hammer is caused to rotate on its axis past the cocking position by the withdrawal of the breech bolt. When the lever is raised to its normal position, the breech bolt presssd home into the chamber, and the carrier depressed to the level of the magazine, simultaneously the spiral main or striker spring is compressed, the hammer revolves forward until the trigger bent is caught in the notch of the tumbler, thus cocking the arm, and the locking bolts are shot up through the breech bolt. The rifle is now ready to be fired.

The magazine is filled, while the breech mechanism is closed, by passing the cartridges through an opening at the right side of the shoe, which is closed by an automatic spring cover. By a very simple arrangement this rifle will take cartridges of slightly varying weights of powder and projectile. These rifles are made in several calibers, from 0·32 in. to 0·45 in.

Vetterli Magazine Rifle.—This arm (see Fig. 7), which has been for some years in use by the Swiss army, has the bolt action of the single loader of the same name. It represents the first class of magazine rifles, the magazine consisting of a tube underneath the barrel. The cartridges are inserted through an aperture at the side of the shoe, as in the Winchester rifle, and are fed to the rear by means of a spiral spring. Indeed, the principle of the "repeating" action is very similar to that of the last named arm, except that the carrier is worked by the bolt instead of by an exterior lever.

On opening the breech, by pulling back the bolt, a stud on the latter strikes against the upper extremity of a bell crank lever, L, and causes the other arm to raise a carrier, H, containing the cartridge, which is thus brought on a level with the chamber of the barrel. When the bolt is pushed forward, the cartridge is sent home into the chamber, and another projection on the bolt, striking the bell crank lever, lowers the carrier to its original position, when it is in readiness to receive another cartridge from the magazine. The Vetterli, which fires a rim fire cartridge, is a heavy and clumsy arm, and cannot now be considered in the first rank of magazine rifles.

Hotchkiss Magazine Rifle.—This rifle (see Fig. 8) was one of the three models recommended by the American board for manufacture in order to undergo an exhaustive practical trial in the hands of the troops. The breech is closed by a bolt of much the usual form, in three parts. A is the hammer or rear piece, B the center piece with handle attached, and D the bolt head, or front piece carrying the extractor. The center piece contains the coiled spiral mainspring encircling the striker, which latter is operated by the trigger in the usual manner, the mainspring having been compressed by the motion of closing the bolt and turning down the handle. There is an arrangement for withdrawing the striker within the bolt head in opening the bolt, and the shape of the slot or recess in the shoe is such that the bolt is cammed forward by turning down the handle, slowly forcing the cartridge home into the chamber. Till this is completely done the rifle cannot be fired.

The magazine is a brass tube in the butt. A hole is drilled in the back of the shoe, below and obliquely to the axis of the bore, and through this hole cartridges are fed into the chamber by the action of the spiral magazine spring. There is a cartridge stop, C, at the front end of the magazine, and when the latter is filled by pressing the cartridges into it through the hole in the shoe, the front cartridge bears against this stop.

Upon pulling the trigger, the cartridge stop, C, is momentarily depressed, and allows the front cartridge to be pushed past it, against the under side of the bolt. When the bolt is drawn back, this cartridge slips quickly into the shoe, while the one following is caught and detained by the stop. It will be seen, therefore, that the motion of pressing the trigger to fire one cartridge permits the next one to partly enter the shoe, the operation being completed when the bolt is withdrawn with the empty case. As has already been stated, the act of closing the bolt presses the cartridge home into the chamber.

There is a small thumb bolt on the right side of the stock, by pushing which forward the magazine can be cut off, and the rifle used as a single loader in the ordinary manner. Pushing it back brings the magazine again into play. On the left side of the shoe is another thumb piece, which, when pushed to the front, prevents all movement of trigger, cartridge stop, or bolt, securely locking the action.

Five cartridges can be carried in the magazine, and one in the chamber.

As a magazine arm, two motions are required for loading, viz., opening and closing the bolt; as a single loader, three movements are required, viz., open bolt, insert cartridge by hand, close bolt.—*Engineering.*

(*To be continued.*)

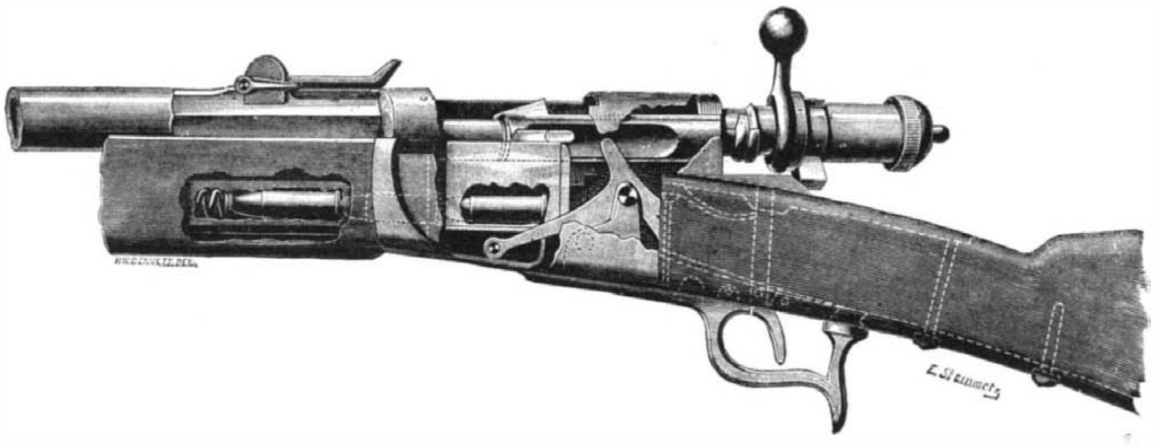


FIG. 7.—THE VETTERLI MAGAZINE GUN.

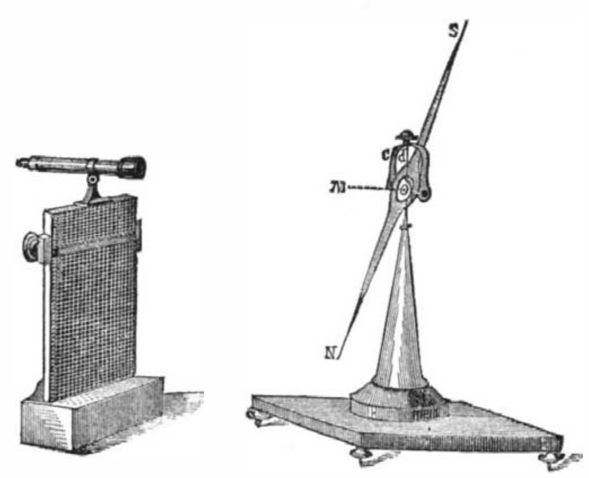
FIG. 8.—THE HOTCHKISS MAGAZINE GUN.

APPARATUS FOR INVESTIGATING TERRESTRIAL MAGNETISM.

A MAGNETIC needle, N S, is suspended on an axis passing exactly through its center of gravity, and is supported by the metallic frame, C, which carries an agate cup bearing, that is poised upon the vertical point, *d*, so that the magnet can move in all directions in the vertical or horizontal planes. Fastened to the center of the magnet is a circular mirror, M, whose reflecting plane passes exactly through the center of gravity of the needle. The observations are made in the usual manner with a telescope with spider lines. In place of a simple scale such as is used with reflecting galvanometers and magnetometers, a board is arranged below the telescope, divided by both horizontal and vertical lines, though the horizontal lines alone would suffice. A graduated rule or scale can be moved up and down over the face of the scale board by means of a button worked by the observer.

The apparatus is so set up that with the needle in the normal, or zero, position as regards variation and declination, the zero of the scale will be reflected. Then in each observation a single reading gives both the local variation and declination or dip. This we regard as important, because observations of the dip are generally made in a perfunctory manner, and it seems a matter of some importance to know the absolute position of the magnetic needle with respect to the axis of the world and to the position occupied by the latter with respect to the sun.

If the observations are to be continuous, a plan highly to be recommended, a good lamp is placed in the position occupied by the telescope, and for the graduated board is substituted a disk covered with sensitized paper (gelatino-bromide) and rotated intermittently one-half a degree per minute by clockwork. The system of continuous photographic registration is due to Mr. Brooke, and has already been successfully applied in observatories. Mr. Brooke uses a cylinder, continuously rotating, instead of a disk.—*U. Bagnoli, in L'Elettricita.*



APPARATUS FOR INVESTIGATING TERRESTRIAL MAGNETISM.

ADULTERATIONS IN FOOD AND DRINK.

The adulteration of articles of food and drink has long been a subject of public disquietude. Accum, in his treatise on adulterations of food (London, 1820), first aroused attention to the subject, and the work begun by him has been prosecuted with greater thoroughness, since, by Mitchell, Normandy, Chevallier, Garnier, Harel, Marat, and, very exhaustively, by Dr. Hassall, whose work on food and its adulterations (1851-1854) comprises upward of 700 closely printed pages.

It is the opinion of Dr. Hassall, after a very thorough examination of the subject, that adulteration prevails in *nearly all* articles used as food, drink, or medicine; and he adds that many of the substances used in the adulterating process are not only injurious to health, but are even poisonous. In Dr. Hassall's investigations, the microscope was the effective instrument of detection, and many of the figures that illustrate these notes were originally drawn by him by the aid of the camera lucida in connection with that apparatus.

Let us submit a few common articles of food and drink to microscopic examination, and see what will be revealed to us.

Milk.—The fatty matter of milk, upon which its value mainly depends, exists in the form of innumerable semi-opaque, white globules of various sizes. In good milk (Fig. 1), these globules are seen under the microscope to be very abundant, and some of them of considerable size. In poor milk, the globules are much less numerous and of smaller size; and in the milk of diseased cows (Fig. 2), they are few in number, of large size, and accompanied with morbid granulations. Cream consists almost entirely of these fat globules, some of which are of considerable size. When cream has been exposed for some time to strong agitation, these fat globules coalesce into a mass, the remaining watery liquid is expelled from between them, and butter is produced. This substance, when unadulterated, appears under the microscope as shown in Fig. 3.

The first milk yielded by the cow after calving, called *colostrum* (Fig. 4), is characterized by the presence of numerous corpuscles of large size and granular appearance. "The disgusting adulteration of milk with cerebral matter, known to be occasionally, although it is to be hoped very rarely, practiced, is readily detected in recent milk by the aid of the microscope, portions of the nerve tubules being discovered in such milk" (Fig. 5).

According to Hassall, the common adulterants of milk are: water, which is difficult of detection when it exists in very small quantity; flour or starch, which may be detected with a small quantity of iodine and turmeric, to give richness of color. Less common adulterants are: gum arabic, gum tragacanth, and dextrine. It has been pointed out by Accum that the prevalent notion that milk is occasionally adulterated with chalk is erroneous, since this substance is entirely insoluble, and would at once fall to the bottom.

Coffee.—Pure ground coffee, when examined under the microscope, presents the appearance shown in Fig. 6. The adulterants of ground coffee are: chiccory, roasted wheat, beans, peas, potato, and burnt sugar. Of these, the most common adulterant is chiccory, which has nothing to recommend it but cheapness, and which is itself scarcely ever free from sophistication. In fact, according to Johnston (Chemistry of Common Life), Venetian red is very commonly employed to impart to chiccory a true coffee color; "and it is curious to observe how the practice of adulteration extends itself from trade to trade. The coffee dealer adulterates his coffee with chiccory to increase his profits; the chiccory maker adulterates his chiccory with Venetian red to please the eye of the coffee dealers; and, lastly, the Venetian red manufacturer grinds up his color with brick dust, that by his greater cheapness, and the variety of shades he offers, he may secure the patronage of the traders in chiccory!" Other adulterants of chiccory are roasted turnips, carrots, parsnips, mangel-wurzel, and beans. A simple method of detecting an admixture of chiccory with coffee is to put the suspected powder in cold water. Chiccory gives a colored infusion in cold water, while coffee does not. When coffee is adulterated with this article, it presents under the microscope the appearance shown in Fig. 7, where *a* represents the coffee, *b* the chiccory, and *c* starch granules from roasted wheat.

Tea.—There is no falling back upon tea as a beverage, for this seems to be used rather worse than coffee. This article is not only adulterated in the countries which import it, but still more so by the Chinese themselves. The favorite adulterant is spent tea leaves, purchased of hotels and restaurants. When these are used, recourse is had to catechu to impart the necessary astringency and color, and to supply the place of the abstracted tannin. Gum and starch are used to restore the twisted form imparted by the Chinese method of drying, sulphate of iron is used to impart a black color, and rose pink to give a bloom to the surface.

Plumbago is used by the Chinese to "face" the leaves of black teas, and some substance resembling China clay or talc is employed for imparting a bloom or luster. The Chinese also adulterate their tea with leaves other than those of the tea plant. As regards the black teas, congous and souchongs, these arrive mostly in a genuine state. Certain others, such as scented orange pekoe and caper, are invariably adulterated by being glazed with plumbago; caper likewise by being mixed with paddy husks and leaves of plants other than those of the tea plant. Fig. 8 shows the appearance, under the microscope, of an imitation tea made in large quantities in China, and offered in foreign markets at a low price. At *aaa* are seen fragments of tea leaves or tea dust; at *bbb*, sand; at *ccc*, starch granules; at *ddd*, granules of plumbago; at *eee*, particles of a mica-like substance; at *ff*, cells of turmeric; and at *gg*, fragments of indigo.

Fig. 9 shows a specimen which contains no tea at all; at *aaa*, we have granules of wheat starch; at *bbb*, fragments of catechu; and at *ccc*, crystalline needles from the catechu.

Green teas, with the exception of those from Assam, are invariably adulterated, that is to say, glazed with coloring matters of different kinds, and some of them highly poisonous. Among them are: Prussian blue, indigo, Dutch pink, verdigris, arsenite of copper,

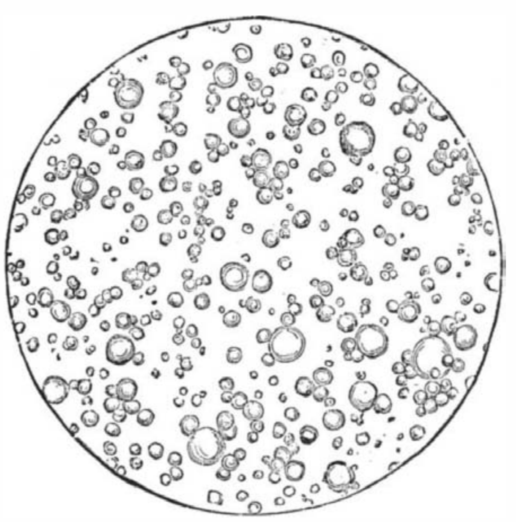


Fig. 1.—PURE COW'S MILK.

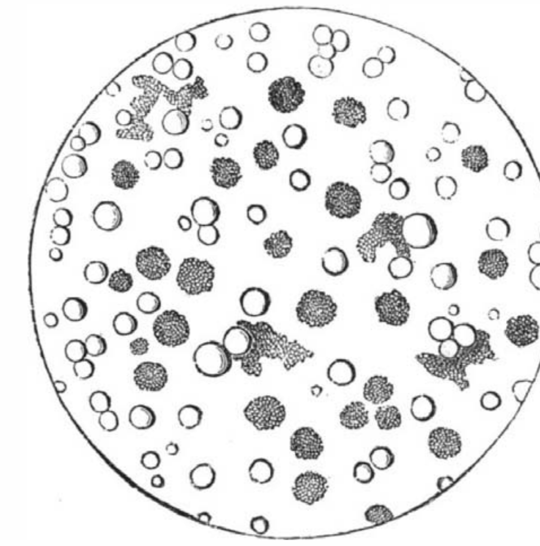


Fig. 2.—MILK OF A DISEASED COW.

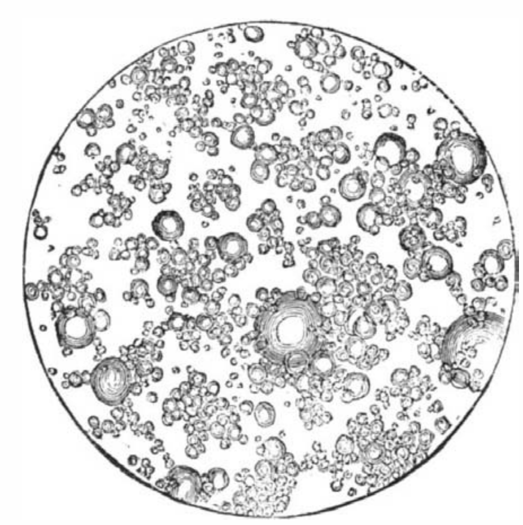


Fig. 3.—PURE BUTTER.

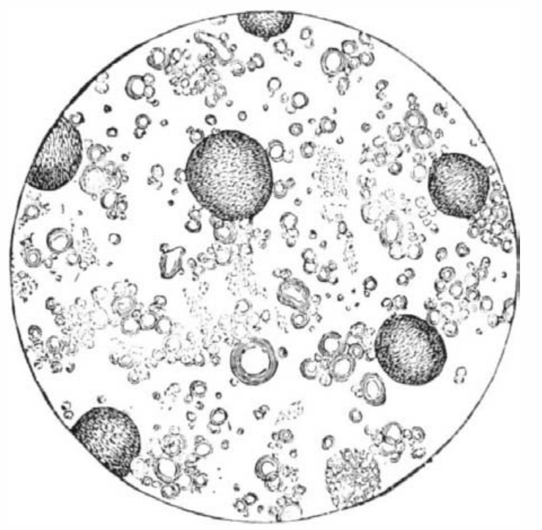


Fig. 4.—COLOSTRUM, OR MILK YIELDED BY THE COW AFTER CALVING.

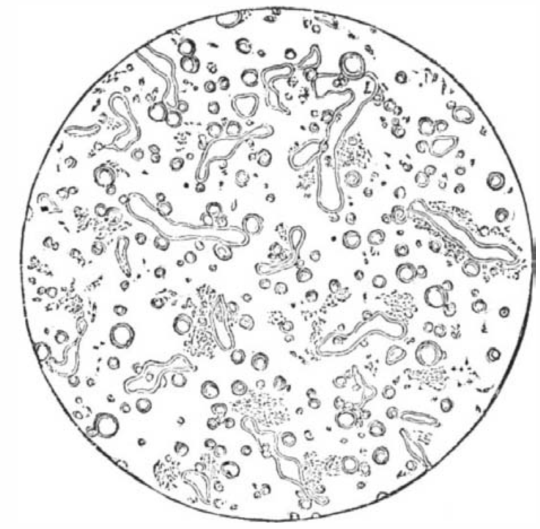


Fig. 5.—MILK ADULTERATED WITH CALFS' BRAIN.

Fig. 6.—GENUINE GROUND COFFEE.

Fig. 7.—ADULTERATED COFFEE.

Fig. 8.—IMITATION CAPER OR GUNPOWDER TEA.

Fig. 9.—IMITATION TEA.

chromate and bichromate of potash, chrome yellow, chalk, etc.

Cocoa and Chocolate.—All the parts of the cocoa bean are found in small fragments in the paste. Fig. 10 shows the microscopical appearance of genuine Trinidad cocoa. At *a* we recognize fragments of the cellular tissue of the bean; at *b*, portions of the rind; at *c*, fragments of the germ; and at *d* and *e*, isolated granules of the peculiar starch of the seed.

As regards chocolate, the processes employed in corrupting the manufacture are described as "diabolical." "It is often mixed with brick dust to the amount of ten per cent., and peroxide of iron twenty-two per cent., and animal fats of the worst description." In England, cocoa is sold under the names of flake, rock, granulated, soluble, dietetic, homœopathic, etc. Such names are evidently employed to disguise the fact that the articles are compounded of sugar, starch, and other substances. Other adulterants are flour, potato starch, cocoa nut oil, lard, and tallow, and, to give weight, chalk and plaster of Paris, and for color, red earth or Venetian red. Fig. 11 shows one of these mixtures as seen under the microscope. It is sold under the name of "Homœopathic Cocoa." At *aaa* are seen granules and cells of cocoa; at *bbb*, granules of canna starch; and at *c*, granules of tapioca starch.

Flour.—Starch almost constantly occurs in the vegetable kingdom in the form of organized corpuscles, the characters of which frequently vary greatly in different plants. These differences are often so great that, with the aid of the microscope, they afford information of a highly valuable character, and allow the observer to distinguish many flours from each other. Wheat flour is frequently adulterated with various substances, such as potato starch, bean flour, Indian meal, rye flour, and rice flour, and with alum, chalk, bone dust, and plaster of Paris. In the detection of such adulterations, the microscope, together with a slight knowledge of the action of chemical reagents, lends important assistance. "It enables us to judge of the size, shape, and markings of the starch grains, and thereby to distinguish the granules of one meal from those of another. In some cases, the microscopic examination is aided by an application of potash. Thus, we may readily detect the mixture of wheat flour with potato starch, or meal of the pea or bean, by the addition of a little water to a small quantity of the flour; then, by adding a few drops of a solution of potash

The adulteration of wheat flour with alum and "stuff" is practiced with a twofold object, viz.: "First, to render flour of bad color and inferior quality white and equal, in appearance only, to flour of superior quality; and secondly, to enable the flour to retain a larger proportion of water, by which the loaf is made to weigh heavier. By dissolving out the alum in water, and then recrystallizing it under the microscope, this adulteration is readily detected."

The starch granules of rye flour, which is sometimes used to adulterate wheat flour, are shown in Fig. 13. For the sake of comparison, we present in Fig. 15 the starch granules of sago, a fecula obtained from the *Sagus Rumphii*, a palm growing in the Moluccas, and those of the arrowroot, a fecula derived from the *Maranta arundinacea*, growing in the West Indies. It is very rare that sago reaches us in the state of purity here shown. And an imitation of the article is sometimes prepared in Europe from potato starch. This imitation, however, when examined under the microscope, exhibits larger granules, which are also

FIG. 10.—GENUINE TRINIDAD COCOA.

FIG. 11.—ADULTERATED COCOA.

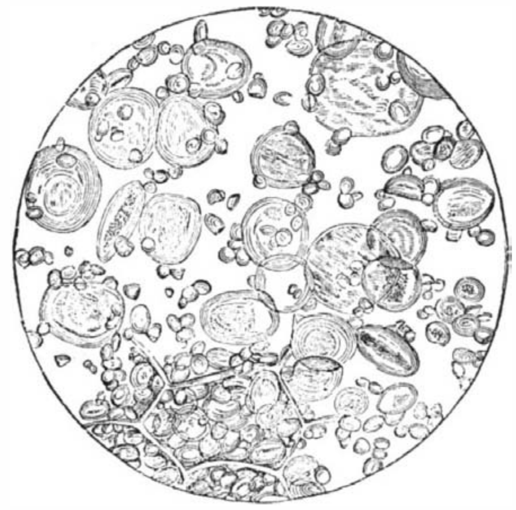


FIG. 12.—STARCH GRANULES OF WHEAT STARCH, AND CHARACTERS OF THE CELLULOSE.

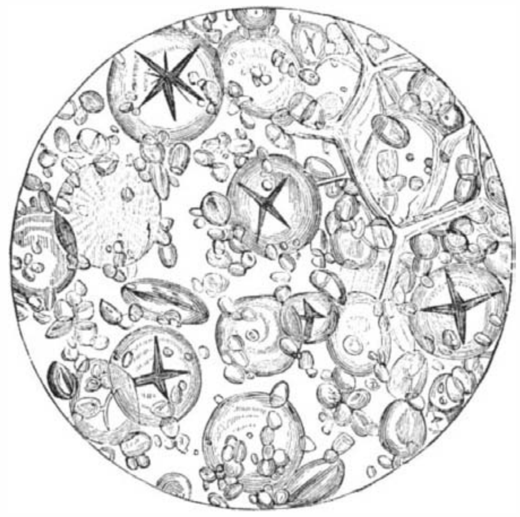


FIG. 13.—STARCH GRANULES OF RYE FLOUR.

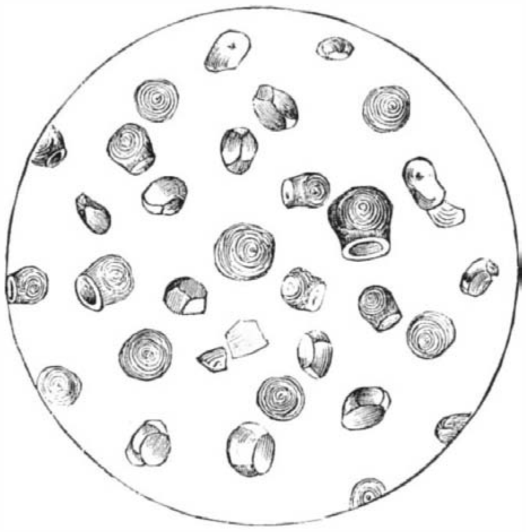


FIG. 14.—GRANULES OF POTATO STARCH.

FIG. 15.—SAGO.

FIG. 16.—ARROWROOT.

(made of the strength of one part liquid potash to three parts of water), the granules of the potato starch (Fig. 14) will immediately swell up and acquire three or four times their natural size, while those of the wheat starch (Fig. 12) are scarcely affected. If adulterated with pea or bean meal, the hexagonal tissue of the seed is at the same time rendered very obvious under the microscope. Polarized light will be of use as an additional aid. Wheat starch presents a faint black cross proceeding from the central hilum, whereas the starch of the oat shows nothing of the kind."

"Adulteration of bread with boiled and mashed potatoes, next to that with alum, is, perhaps, the one which is most commonly resorted to. The great objection to the use of potatoes is that they are made to take the place of an article very much more nutritious. The cells which contain the starch corpuscles are, in the potato, very large (Fig. 14); in the raw potato, they are adherent to each other, and form a reticulated structure, in the meshes of which the well defined starch granules are clearly seen; in the boiled potato, however, the cells separate readily from each other, each forming a distinct article. The starch corpuscles are less distinct and of an altered form."

more regularly oval or ovate, smoother, less broken, and more distinctly marked with the annular rugæ than those of sago. Arrowroot is often adulterated with common or potato starch, but the sophistication may, as in the preceding case, be easily detected with the microscope.

THE RELATION BETWEEN DRINKING WATER AND TYPHOID FEVER.*

By DOWLING BENJAMIN, M.D., Camden, N. J.

TYPHOID fever is caused by a peculiar and specific poison. I do not know that this is denied to-day by any one competent, from careful study and thorough investigation, to give trustworthy information on this subject. Does it arise *de novo*? All the investigations that I have made have proved to my mind that the poison which produces typhoid fever cannot be generated spontaneously, but must come from another source. I am aware that there are some gentlemen who even now believe that it originates *de novo*, and they give the examples and cases which prove to their minds the truth of such belief. But the cases cited as proofs are generally defective, and do not exclude the possibility of infection from a preceding case. Take for example the four instances given by Dr. R. W. Hutchinson, of Queens County, N. Y., published as late as October 9, 1886, in the *Medical and Surgical Reporter*.

I will not occupy your time by criticising all these cases, but will select the fourth, which seems to be the strongest, as follows:

"IV. In the last part of August, 1885, a party of young folks, numbering some fifteen, started out to spend the day at the banks of a creek near East Rockaway. They carried no water with them, but relied on securing a supply from a sunken barrel near the creek, that had been used for that purpose for a number of years. On this occasion it was noticed that the water smelled and tasted bad, so much so that some of the party refused to drink it. Exactly one week from the day of the picnic most of them who had drunk the water, some nine in number, were stricken down abruptly with typhoid fever. I regret very much that I did not have the opportunity of examining the barrel, with its contents, immediately after the picnic, as I am now left in doubt as to the cause of the decomposition in the water. Shortly after the outbreak of the fever some person, fearing that others might drink, pulled up the barrel and destroyed the well. But from a number of reasons I can positively say that there was no possibility of the water being contaminated with the fecal matter of a patient suffering from typhoid fever, which is the recognized way of communicating the disease; and if the germs of the disease did not originate *de novo* in the well water, I ask the question, Where did they come from?"

You see he gives no reason why the well could not be contaminated with typhoid fever, though he says he has a number of them; yet he says he had no opportunity of examining the barrel, nor its contents, but he *heard* some of the party say that the water tasted and smelled bad. Notice that in less than seven days most of the party of nine who drank the water were suddenly stricken down. This fact, in itself, might occasion some doubt of the fever being a true typhoid, as the incubation period of typhoid fever is usually longer, though there are instances on record which would have a tendency to show that typhoid fever may occur with a shorter incubation period than two weeks. Two weeks, however, is about the usual time.

What a blessing it might have been if the doctor had only told us the precious little secret of how he knew that no one had been in that vicinity, that his fecal matter might have affected the well!

Then take the cases cited by the illustrious Morchison, who has done so much for the thermometry of typhoid fever, but who has, perhaps, led astray more students of the origin of the poison than any other man. None of his cases is in my opinion conclusive, and this opinion is sustained, also, by the opinion of Dr. J. H. Hutchinson, of Pennsylvania, who says, in an article on this subject, that the cases referred to are by no means convincing (see p. 256, "System of Medicine by American Authors," just published).

A case put forward by the advocates of the spontaneous origin theory as one of their strongest is that reported by R. Bruce Lowe, Medical Officer of Health, Holmesley, Yorkshire, published in the *British Medical Journal* in 1880. "It occurred," he says, "in a lad who had not been away from home for months. No stranger had visited the house, and there was no fever

* Read at the twelfth annual meeting of the New Jersey Sanitary Association, Saturday, November 20, 1886.

in the district." But Mr. Lowe admits there was a case before, only eight months past, and only eight miles distant, and he does not prove there was no possibility of infection, either by domestic animals or by streams of water. It is a well-known fact that, when the great forests of *pine* are cut off the land in the northern part of the United States, there comes up a thick growth of *oak* timber immediately succeeding; and the common opinion of people who notice this strange phenomenon is, that the little *oak plants originate spontaneously* in the soil. I think you will hardly believe this correct; but the same agencies that sowed the original oak seeds in the forest, it must be admitted, are fully competent to sow the seeds of typhoid fever in unexpected places occasionally. The man who starts out, in this present age of scientific research, to prove that typhoid fever originates *de novo* assumes a greater task than Hercules.

No combination, either of filth, fecal matter, or sewer gas, has ever yet been discovered that will produce the disease.

What are the physical characteristics of the virus of typhoid fever? Is this virus a liquid, a solid, or a gas? Evidently it is matter of some kind. Inorganic matter may be either solid, liquid, or gas; organized matter is never liquid, never gas. We conclude it is not a gas for the following reasons:

First, the gas has not been isolated.

Second, it would be more apt to go through the air than otherwise, which is not the case with this virus.

Third, all known gases that affect the system profoundly, if they affect it at all, do so at once or in a few minutes after their reception into the system.

Can a dose of carbonic acid gas, ammonia gas, illuminating gas, or any other poisonous gas, be taken and lie in the system for from two to six weeks, and then begin to develop a train of trouble, a uniform succession of symptoms, like typhoid fever, or small-pox, or any other of the zymotic diseases? Never. Is it a liquid, this virus? The same objections apply to this theory that apply to the theory of its being a gas. Is it composed of solid particles? If so, these particles must be of nearly the same specific gravity as water. There is no evidence to the contrary, at any rate, and these solid particles must be very small indeed, for water known to contain typhoid fever poison is often apparently clear and bright. Filters do not seem capable of sieving out these particles, these poisonous particles and this matter. At least water has been filtered through ten and even one hundred feet of sand and earth, coming out clear, but still bearing poison in sufficient quantities to produce fever and cause death. So far as is at present known, the poison has not been filtered out of the water by any kind of filter. This would lead us to think it was really dissolved in the water, but for the fact that a system of very fine filtration has not been tried upon suspected water, and then the water given to persons to drink, to see if the disease would be produced by it. There is no case on record of any person ever having taken the disease from water that has been boiled, thus showing that, as far as known, the boiling temperature destroys the poison.

The theory that the poison of typhoid is an organized poison, or germ, or bacillus, seems to explain its action more completely than any other. This phase of the subject was carefully discussed, and its progress given at length, by me in an essay written in 1876, and published in *The Country Practitioner*, vol. ii., Nos 6 and 7. Whatever may be considered the nature of this virus, the fact *that water is its principal distributor is certain.* Indeed, a careful study of the cases and statistics that I have examined seems conclusive that at least ninety-five per cent. of the cases of typhoid fever come directly from the water. The poison which produces this disease does not go through the air. All physicians now permit people to go into the sick room where this disease exists. Visitors, and those who wait on the patients, do not take the disease. The washerwoman has been known, in rare instances, to take the disease from the water containing the soiled linen, which has infected her hands and gotten into the mouth and absorbents. The infected wash water is very often thrown on the ground near a well, or into the sewer, with the more poisonous dejecta. I have seen two cases that occurred among sailors who drank water from the Delaware River, opposite the Philadelphia sewers.

There is one instance* where it has also been shown that cattle have been afflicted with this disease. But in tracing the disease still further back, it was found that the cattle caught the disease from drinking infected water, and thus the milk supply has also been known to become affected. So the more we investigate the subject, the more strikingly the fact stands out that water is the main habitat of the poison. Several facts show, also, that when water contains a little organic matter, the virus will be active for at least a year, in still water, and very probably for a number of years, as some of these cases cited prove.

Recent investigations show the intimate relations of this disease to drinking water to be so close and so constant that it is hardly ever worth while to think of any other source of the contagion.

One of the most remarkably clear examples of this relation of drinking water to typhoid fever occurred at Plymouth, a small city in Luzerne County, Pa.; and for the invaluable lessons taught by this epidemic we owe much to the committee sent by the mayor of Philadelphia to investigate the subject, and it is a plain and perfect explanation of the case. The explanation is as follows:

"The mountain stream is a small one, running down over a rocky bed, and on a declivity not eighty feet from its bed a dwelling is situated, wherein, during January, February, and March, was located a case of typhoid fever that is only now convalescent, the worst period of the case being about the 30th of March. The attending nurse was in the habit, during each night, of carrying the excreta from the patient and depositing it on the ground toward the stream. The ground during all this time was frozen and covered with snow, until the thaw and rain already alluded to occurred. The poisonous character of the dejecta is not destroyed by freezing, but is only kept in a state of hibernation.

"A great part of the three months' accumulation of dejecta was suddenly swept into the rapidly running stream, and reached the lower reservoir as quickly as a man walking fast could have arrived there.

"In fifteen days from this time the epidemic began, fifty cases occurring daily between the 10th and 20th of April. Up to the present, twelve hundred have been sick and one hundred have died out of a population of eight thousand. For the first three weeks the few people in the town who used well water exclusively escaped the disease. The period of incubation varies between ten and twenty days, or longer, and therefore no other conclusion can be arrived at than that the infective poison existed in the mountain water and originated from the one case of fever in the house on the side of the stream."

This entire and comprehensive report is on file in the mayor's office, Philadelphia, and is also published in the "Proceedings of the County Medical Society," May 13, 1885. The committee consisted of M. S. French, A.M., M.D., Surgeon of the Police Department of Philadelphia, and E. O. Shakespeare, A.M., M.D., Pathologist of the Philadelphia Hospital.

Last October a severe epidemic of typhoid was in progress in Imlaystown, N. J., about forty miles from Camden, and I went out there to investigate it, and was greatly assisted in so doing by the kindness of Dr. H. G. Norton.

I found that a brook about four feet wide runs through the village. A street runs parallel with the stream, about one hundred feet from it. A row of houses is situated between the brook and the street, and the back yards extend to the brook, about forty feet distant. Between the brook and the houses is situated a row of privies, and a row of wells for drinking water. The privies are situated on the bank of the brook, so that the fecal matter from them has to run only a distance of three or four feet to get into the stream. The wells are between the stream and dwelling houses, and about thirty or forty feet from the brook. The somewhat impervious stratum has a slight dip toward the well, and underlies the locality. On measuring, it was found that the floor or bottom of the wells was not more than a few inches below the floor of the brook, and when the water was high in the brook it was also high in the wells, and that there was porous ground between the brook and the wells of the privies.

Beginning up the stream, and designating the houses, which are but a few feet apart—not over fifty feet—and numbering from 1 to 3, I will give you the following explanation:

In 1883 a family came to No. 2 suffering with "typhoid malarial fever and diarrhœa." The children had fever and bowel trouble, with diarrhœa, lasting for months, until the spring of 1885. On August 14, 1885, a young lady was taken with typhoid fever in this same house. On August 28, another young lady was taken with the disease in No. 2, the next house below—down the stream. August 27, patient at No. 3 took the disease. September 12, another patient took the disease in No. 3. In September a relative of the family in No. 2 visited the town, drank the water, and died in a few weeks afterward of typhoid fever. September 30, a patient opposite to No. 2 took the disease. In the spring of 1886 the family had moved out of No. 2; the well had been kept closed, and had not been cleaned out. A new family moved into No. 2 in April or May, 1886. The boys drank the well water, in spite of protests, and took the disease in June, 1886. One of the brothers died. The girls, who would not drink the water, escaped the disease.

An analysis of this water from the wells, by Professor H. B. Cornwall, of Princeton College, showed the water to be thoroughly contaminated with fecal matter. Evidently the virus had remained in one of these wells; a year had passed, and yet the winter had not been able to kill it.

The length of time that the virus will remain active has not been ascertained, but it is known to be years, in water that is not much disturbed.

I have cited these examples because they are so recent and so near at hand. Hundreds of instances might be cited, and the evidence piled up almost *ad libitum;* but, if further examples would not be superfluous in this paper, the time—twenty minutes—allotted to me would preclude my citing them here, and I might say now that much of the data upon which my remarks have been based are not included in this paper for the same reasons.

In the face of what is already known, I do not think that any student of sanitary science can deny that the poison of typhoid may be carried by the water supply. I do not know that any do; *but the extent to which it is carried by water and the preventability of the same are the great points* that do not seem to be sufficiently appreciated by us, and scarcely appreciated at all by the people in general.

If the people can be made to understand that almost all the cases of typhoid fever come from the water supply, and that there is no disease more easily prevented than this, we shall have accomplished the first great step toward the annihilation of one of the worst destroyers of mankind.

Look at the dreadful suffering caused in Philadelphia and Camden to-day by ignorance or indifference to these facts. Only a few days ago a noble wife and young mother died in our city of this dread disease, thus blighting the prospects of a happy family; and as I stood by her bedside, I could but regret that another life had been needlessly sacrificed.

The disease cannot occur without the virus to produce it, and the virus can be kept out of the drinking water, and it should be kept out at any cost. It would pay at *any* price. Every death that is preventable is needless, and is a reproach to the community. Dr. E. O. Shakespeare, an eminent investigator of contagious diseases, who has been sent abroad by the highest executive authority of the United States, to investigate the nature and causes of cholera, says, in the *New York Medical Journal*, January, 1885, that "epidemics of typhoid fever are absolutely preventable and controllable, and neglect to employ proper means to this end should be regarded as inexcusable."

Great reforms and revolutions have taken place within our own recollection; and the student of science dares to indulge the hope that, even during his short life, he may have the pleasure of seeing the death rate from typhoid fever reduced more than ninety per cent.—*Medical Record.*

* Closter, Germany, 1878; Berlin. klin. Wochenschrift.

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