The water-carriage system of sewerage will be noticed here under its three aspects:—(1) the ultimate disposal of sewage; (2) the system of common sewers by which sewage is conveyed to its destination; (3) the domestic arrangements for the collection of sewage.

I. The Ultimate Disposal of Water-carried Sewage.—In the water-carriage system of sewerage the fertilizing elements are so largely diluted that it becomes a matter of the utmost difficulty to turn them to profitable account. It has been estimated that every ton of London sewage contains ingredients whose value as manure is rather more than 2d.,[1] a value which, could it be realized, would make the sewage of the metropolis worth a million and three quarters sterling per annum. Sewage farming, however, does not pay. After much costly experiment the conviction is gaining ground that, neither by applying sewage directly to land, nor by any process of chemical treatment that has yet been proposed, can sewage be made to yield a return as manure which will cover the cost of its transport, treatment, and distribution, except perhaps in a few cases where the circumstances are peculiarly favourable.

Sewage farms.

At the same time, sewage farming does afford one satisfactory solution of the problem of how to dispose of sewage without creating a nuisance—a problem in which any question of profit or loss is of secondary importance. A very early instance of irrigation by sewage is that of the Craigentinny Meadows, a sandy tract of 400 acres, on which part of the sewage of Edinburgh has been discharged during certain seasons for nearly a century. There, owing to favourable conditions, and to the fact that complete purification of the sewage is not attempted, the process yields a profit; but no such result could be looked for if the sea were not at hand to receive the imperfectly cleansed sewage and the wholly uncleansed surplus. Germany furnishes a still older example of irrigation in the sewage farm of the town of Bunzlau, which has been in existence for more than three hundred years.

Five methods of treating sewage may be named, of which two or more are often found in combination.

Discharge into the Sea or into a large watercourse is in general the least costly means by which a community can rid itself of its sewage. Much care in the choice of outlets is necessary to make this plan effective in avoiding nuisance. Some towns make use of tanks or outlet-sewers of large capacity, from which the discharge is allowed to occur only when the tide is ebbing. When the volume of sewage is very large, even this precaution does not wholly protect the neighbouring coast from foul deposits. A striking instance is furnished by the case of London, which discharges its sewage into the tidal estuary of the Thames at Barking and Crossness during only some three or four hours from the time of each high tide. It is found that the discharged matter is washed up and down the river with every tide, occasionally reaching as far up as Teddington, and that the portion which is not deposited in the form of mud banks only very slowly works its way to the sea.

Broad Irrigation.—By this is meant the use of sewage to irrigate a comparatively large tract of cultivated land, in the proportion of about 1 acre (or more) of land to every 120 persons in the sewage-contributing population. This system is now largely and successfully used, especially where the soil is a porous sandy loam. Fears that the farms would prove dangerous to the health of the neighbouring district, and that the crops and vegetables grown on them would be unwholesome, have proved groundless. When the farm is properly laid out and carefully managed the effluent water is pure enough to be admitted to a clear stream from which water-supply is drawn. Broad irrigation is practised at Croydon, Cheltenham, Blackburn, and many other English towns; and it has recently been applied, on a very large scale, to dispose of the sewage of Berlin.

Intermittent Downward Filtration.—This is another mode of purifying sewage by applying it to land, which differs from broad irrigation in requiring a much smaller area in proportion to the sewage dealt with. In 1870 Dr Frankland[2] drew attention to the fact that if sewage were passed through porous soil, not continuously but at intervals long enough to let the soil become aerated, rapid purification took place through the oxidizing action of the air which the soil held in its pores. He estimated that an acre of suitable ground, well furnished with subsoil drains to remove the water after percolation, could in this way take the sewage of 2000 persons. This estimate is now considered excessive, and 1000 persons to the acre is a more recent limit. Mr J. Bailey-Denton at once took up Dr Frankland's suggestion, and in his hands the system of intermittent filtration through land has been successfully applied to the sewage of many towns.[3] The land which constitutes the filter is used to grow vegetables and other crops. Clay soils are, as far as possible, avoided, and the land is thoroughly underdrained at a depth of about 6 feet. The sewage is distributed over the surface in open channels, the proper laying out of which is an important item in the cost of the system, but is essential to its success. When the number of persons exceeds 500 per acre it is advisable to precipitate the solid matter that is held in suspension before the liquid is applied to the land, in order to prevent the surface of the ground from becoming clogged with sewage sludge. Mr Bailey-Denton has pointed out the advantage which the system of intermittent filtration offers as a supplement to broad irrigation, where that is carried out. A serious objection to the disposal of sewage by irrigation is the fact that the farmer must take the sewage always,—at times when it hurts the land as well as at times when the land wants it. But by laying out a portion of the land as a filter bed the sewage may be thrown on that whenever its presence on the remainder would do harm rather than good. Mr Denton has applied this combined system in several instances, and insists, apparently with much reason, that such a combination offers a better prospect of profit than any other efficient mode of purifying sewage. The system of intermittent filtration through land has been recommended by the Royal Commission of 1882–84 as a mode of treating London sewage.

Filtration through Artificial Filters of sand, gravel, ashes, charcoal, coke, peat, &c., though often experimented on, can scarcely be described as an actual system. It is attended by the difficulty that the filter becomes speedily choked by the deposit of sludge. The intermittent use of a suitable artificial filter will, however, serve efficiently to oxidize and therefore purify the liquid portion of sewage from which the sludge has been previously precipitated, and filtration through coke is used in some instances as a supplement to the process which is next to be described.

Chemical Treatment, or Precipitation.—When sewage is allowed to stand, or to flow very slowly through a large tank, a gradual subsidence of the solid particles takes place. The subsidence is, however, much too slow to be complete before decomposition sets in. But it may be very greatly accelerated by the addition of certain reagents, with the object of producing a precipitate which, in falling, will carry down with it the minute particles of solid matter that are suspended throughout the mass. Lime is the substance most usually employed. It is introduced in the form of milk of lime, and in the proportion of about one ton of lime to one million gallons of sewage. When thoroughly mixed, the liquid is left at rest, and a rapid separation of the sewage follows, into a comparatively clear supernatant liquid and a glutinous precipitate or "sludge." The sludge has little value as manure, for the best agricultural constituents of sewage are contained in solution, and very little of the soluble matter is carried down in the deposit. The sludge is dried by being strained over beds of slag, pressed into blocks for transport, and got rid of by being burnt or dug into the ground or thrown into the sea. It has been used in the manufacture of bricks and of cement (Scott's process), but in general it can be disposed of only at a loss. The clarified effluent still contains dissolved organic matter, and may be admitted into running streams only when a high standard of purity is not compulsory. When, however, the volume of the running water which it enters is relatively very large a quick purification takes place by means of the oxygen which the water carries in solution.

The lime process is practised, without further purification of the effluent water, at Leeds and at Burnley. At Bradford, after precipitation by lime, the effluent is filtered through beds of coke-breeze. At Birmingham the sewage of 600,000 people, after clarification by lime (which also serves to neutralize the acid contributed by manufactories), is used to irrigate a farm of 1200 acres.

Very many patents have been obtained for the precipitation of sewage by other chemicals in place of or in addition to lime. In Hillé's process lime is the chief ingredient, with tar and chloride of magnesium or calcium added. At Coventry the precipitants are sulphate of alumina, protosulphate of iron, and lime, and the effluent is afterwards filtered through land, in the proportion of 1 acre to 5000 of the population.

Sillar's "ABC" process, worked by the Native Guano Company at Aylesbury, differs from others in producing a sludge which has considerable value as manure. An emulsion of clay and carbon with a little blood is first mixed with the sewage; a precipitating solution of alum is then added, and the mixture

[1] Hoffmann and Witt, *Report to the Government Referees on Metropolitan Drainage*, 1857.

[2] *Report of the Rivers Pollution Commissioners*, 1870.

[3] J. Bailey-Denton, *Intermittent Downward Filtration, with notes on the Practice and Results of Sewage Farming*, 1st ed. 1880, 2d ed. 1885.

is allowed to settle. The process gives a remarkably clear effluent; practically the whole of the insoluble constituents of the sewage and a portion of the dissolved impurities are carried down in the precipitate, which, when dried and ground along with some sulphate of magnesia, is sold under the name of native guano. The ABC process has been in successful use for nine years at Aylesbury, where the "guano" finds a sale at 70s. per ton. In 1870 the Rivers Pollution Commissioners reported unfavourably on the process, a fact which may have prevented its adoption by other towns, but it has since then received the approval of many specialists. A recent protracted investigation by Dr C. M. Tidy and Prof. Dewar showed that the percentage of oxidizable organic matter removed by the process ranges from 75 to 86—a result, in their judgment, satisfactory. At Leeds, where the process was tried for a time, it was given up because the effluent was purer than the river into which it ran, and the simple lime-process, which costs less but gives a less clear effluent, was adopted in its place.

Much difference of opinion still exists as to the relative merits of broad irrigation, filtration through land, and chemical treatment, as means of disposing of sewage. That either of the two first plans or a combination of them both can be made to yield a satisfactory solution of the sewage problem, from a hygienic point of view, seems unquestionable. That chemical treatment, especially if supplemented by filtration through land, will also purify well, is generally admitted. No process of effective purification is now expected to yield a profit; but the question of cost, on which the choice of a system principally turns, is too extensive to be touched in this article.

II. The Conveyance of Sewage.—For small sewers, circular pipes of glazed earthenware or fire-clay or of moulded cement are used, from 6 inches to 18 inches and even 20 inches in diameter. The pipes are made in short lengths, and are usually jointed by passing the end or spigot of one into the socket or faucet of the next. Into the space between the spigot and faucet a ring of gasket or tarred hemp should be forced, and the rest of the space filled up with cement, not clay. The gasket prevents the cement from entering the pipe, and so obstructing the flow; at the same time it forms an elastic packing which serves to keep the successive lengths of pipe concentric, even if the cement should fail. The pipes are laid with the spigot ends pointing in the direction of the flow, with a uniform gradient, and, where practicable, in straight lines. In special positions, such as under the bed of a stream, cast-iron pipes are used for the conveyance of sewage. Where the capacity of an 18-inch circular pipe would be insufficient, built sewers are used in place of earthenware pipes. These are sometimes circular or oval, but more commonly of an egg-shaped section, the invert or lower side of the sewer being a curve of shorter radius than the arch or upper side. The advantage of this form lies in the fact that great variations in the volume of flow must be expected, and the egg-section presents for the small or dry-weather flow a narrower channel than would be presented by a circular sewer of the same total capacity. Figs. 1 and 2 show

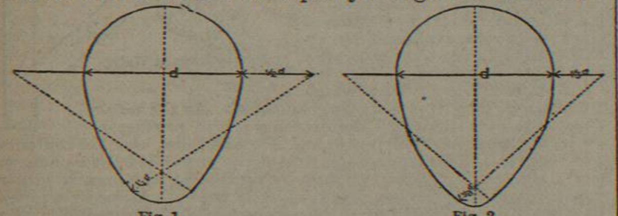

Fig. 1. Fig. 2.

Figs. 1, 2.—Forms of Sewers.

two common forms of egg-sections, with dimensions expressed in terms of the diameter of the arch. Fig. 2 is the more modern form, and has the advantage of a sharper invert. The ratio of width to height is 2 to 3.

Built sewers are most commonly made of bricks, moulded to suit the curved structure of which they are to form part. Separate invert blocks of glazed earthenware, terra-cotta, or fire-clay are often used in combination with brickwork. The bricks are laid over a templet made to the section of the sewer, and are grouted with cement. An egg-shaped sewer, made with two thicknesses of brick, an invert block, and a concrete setting, is illustrated in fig. 3. Concrete is now very largely used in the construction of sewers, either in combination with brickwork or alone. For this purpose the concrete consists of from 5 to 7 parts of sand and gravel or broken stone to 1 of Portland cement. It may be used as a cradle for or as a backing to a brick ring, or as the sole material of construction by running it into position round a mould which is removed when the concrete is sufficiently set, the inner surface of the sewer being in this case coated with a thin layer of cement.

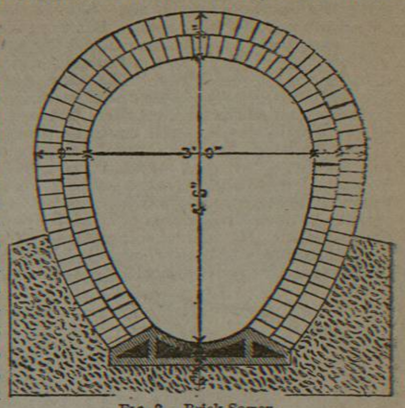

Fig. 3.—Brick Sewer.

In determining the dimensions of sewers, the amount of sewage proper may be taken as equal to the water supply (generally about 30 gallons per head per diem), and to this must be added an allowance for the surface water due to rainfall. The latter, which is generally by far the larger constituent, is to be estimated from the maximum rate of rainfall for the district and from the area and character of the surface. In the sewerage of Berlin, for example, (one of the most recent instances of the combined water-carriage system applied on a large scale), the maximum rainfall allowed for is $\frac{7}{8}$ of an inch per hour, of which one-third is supposed to enter the sewers. In any estimate of the size of sewers based on rainfall account must of course be taken of the relief provided by storm-overflows, and also of the capacity of the sewers to become simply charged with water during the short time to which very heavy showers are invariably limited. Rainfall at the rate of 5 or 6 inches per hour has been known to occur for a few minutes, but it is altogether unnecessary to provide (even above storm-overflows) sewers capable of discharging any such amount as this; the time taken by sewers of more moderate size to fill would of itself prevent the discharge from them from reaching a condition of steady flow, and, apart from this, the risk of damage by such an exceptional fall would not warrant so great an initial expenditure. Engineers differ widely in their estimates of the allowance to be made for the discharge of surface water, and no rule can be laid down which would be of general application.

In order that sewers should be self-cleansing, the mean velocity of flow should be not less than $2\frac{1}{2}$ feet per second. The gradient necessary to secure this is calculated on principles which have been stated in the article Hydromechanics (*q.v.*). The velocity of flow, V, is

$$V = c\sqrt{im},$$

where i is the inclination, or ratio of vertical to horizontal distance; m is the "hydraulic mean depth," or the ratio of area of section of the stream to the wetted perimeter; and c is a coefficient depending on the dimensions and the roughness of the channel and the depth of the stream. A table of values of c will be found in § 90 of the article referred to. This velocity multiplied by the area of the stream gives the rate of discharge. Tables to facilitate the determination of velocity and discharge in sewers of various dimensions, forms, and gradients will be found in Mr Latham's and other practical treatises.

Where the contour of the ground does not admit of a sufficient gradient from the gathering ground to the place of destination, the sewage must be pumped to a higher level at one or more points in its course. To minimize this necessity, and also for other reasons, it is frequently desirable not to gather sewage from the whole area into a single main, but to collect the sewage of higher portions of the town by a separate high-level or interception sewer.

Sewer gas is a term applied to the air, fouled by mixture with gases which are formed by the decomposition of sewage, and by the organic germs which it carries in suspension, that fills the sewer in the variable space above the liquid stream. It is universally recognized that sewer gas is a medium for the conveyance of disease, and in all well-designed systems of sewerage stringent precautions (which will be presently described) are taken to keep it out of houses. It is equally certain that the dangerous character of sewer gas is reduced, if not entirely removed, by free admixture with the oxygen of fresh air. Sewers should be liberally ventilated, not only for this reason, but to prevent the air within them from ever having its pressure raised (by sudden influx of water) so considerably as to force the "traps" which separate it from the atmosphere of dwellings. The plan of ventilation now most approved is the very simple one of making openings from the sewer to the surface of the street at short distances,—generally shafts built of brick and cement,—and covering these with metallic gratings. Under each grating it is usual to hang a box or tray to catch any stones or dirt that may fall through from the street, but the passage of air to and from the sewer is left as free as possible. The openings to the street are frequently made large enough to allow a man to go down to examine or clean the sewers, and are then called "manholes." Smaller openings, large enough to allow a lamp to be lowered for purposes of inspection, are called "lampholes," and are often built up of vertical lengths of drain-pipe.

To facilitate inspection and cleaning, sewers are, as far as possible, laid in straight lines of uniform gradient, with a manhole or lamphole at each change of direction or of slope and at each junction of mains with one another or with branches. The sewers may advantageously be stepped here and there at manholes. Sir R. Rawlinson has pointed out that a difference of level between the entrance and exit pipes tends to prevent continuous flow of sewer gas towards the higher parts of the system, and makes the ventilation of each section more independent and thorough. When the gradient is slight, and the dry-weather flow very small, occasional flushing must be resorted to. Flap valves or sliding penstocks are introduced at manholes; by closing these for a short time sewage (or clean water introduced for the purpose) is dammed up behind the valve either in higher parts of the sewer or in a special flushing chamber, and is then allowed to advance with a rush. Many self-acting arrangements for flushing have been devised which act by allowing a continuous stream of comparatively small volume to accumulate in a tank that discharges itself suddenly when full. A very valuable contrivance of this kind is Mr Rogers Field's siphon flush tank, shown in fig. 4. When the liquid in

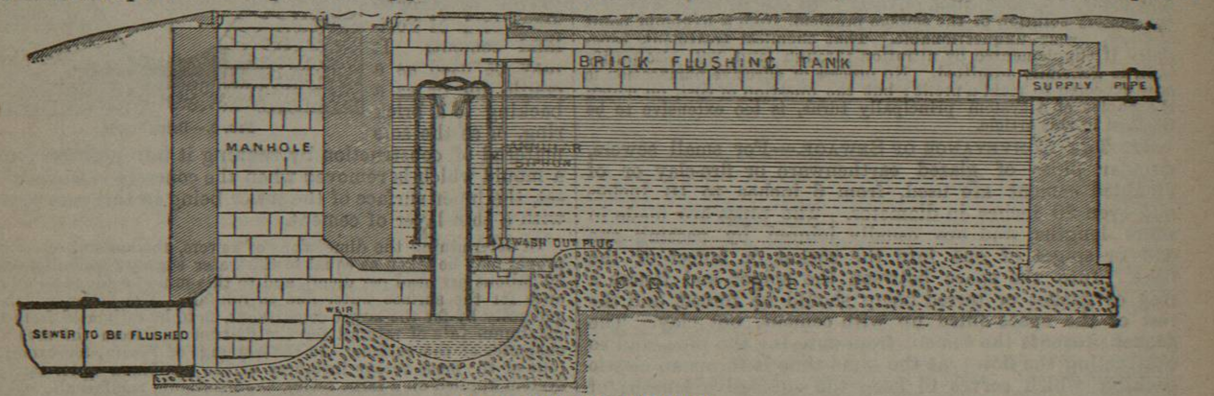

Fig. 4.—Field's Siphon Flush Tank.

the tank accumulates so that it reaches the top of the annular siphon, and begins to flow over the lip, it carries with it enough air to produce a partial vacuum in the tube. The siphon then bursts into action, and a rapid discharge takes place, which continues till the water level sinks to the foot of the bell-shaped cover.

Domestic sewerage.

III. Domestic Sewerage.—In the water-carriage system each house has its own network of drain-pipes, soil-pipes, and waste-pipes, which lead from the basins, sinks, closets, and gullies within and about the house to the common sewer. These must be planned to remove sewage from the house and its precincts quickly and without leakage or deposit by the way; the air within them must be kept out of the dwelling, by placing a water-trap at every opening through which sewage is to enter the pipes, and by making all internal pipes gas-tight; the pipes must be freely ventilated by a current of fresh air, in order to oxidize any deposited filth and to dilute any noxious gas they may contain; finally—and this is of prime importance—the air of the common sewer must be rigorously shut out from all drains and pipes within the house. To disconnect the pipes of each individual house from the atmosphere of the common sewer is the first principle of sound domestic sanitation. When this is done the house is safe from contagion from without, so far as contagion can come through sewer gas; and, however faulty in other respects the internal fittings may be, the house can suffer no other risk than that which arises from its own sewage.

Primary requisites.

Protection against the passage of gas through openings which admit of the entry of water is secured by the familiar device known as the water-trap.

The simplest and in many respects the best form of trap is a bent pipe or inverted siphon (fig. 5) which is sealed by water lying in the bend. The amount of the seal (measured by the vertical distance between the lines a and b) varies in practice from about $\frac{1}{2}$ an inch to 3 inches. If the pressure of air within the pipe, below the trap, is greater than that of the air above the trap by an amount exceeding the pressure due to a column of water equal in height to the seal, the trap will be forced and air will bubble through. This is one way in which a trap may fail, but this may be prevented by sufficient ventilation of the pipe below the trap. Other possibilities of failure are, however, only too numerous. If the pipe is disused for some time, the water may evaporate so considerably as to break the seal. The pipe, if of lead, may bend out of shape, or it may even be so badly set in the first instance as to make the trap inoperative. The seal may be broken by the capillary action of a thread or strip of cloth, hanging over the lip of the trap and causing the water to drain away. A rush of water down the pipe, suddenly arrested, may pass the trap with such momentum as to leave it wholly or partly empty. Another and a common cause of failure can be explained by reference to fig. 5. Let a column of water rush down the soil-pipe c from a closet or sink which discharges into it at some higher point. As the water passes the junction with the branch d it will produce a partial vacuum in the branch, and so tend to suck over the contents of the trap. This process, which is sometimes called the siphonage of traps, can be guarded against by ventilating the branch, either by a separate ventilating pipe leading to the open air or by a pipe e (shown by dotted lines) connecting the top of the branch d with a point sufficiently far up on the soil-pipe to be above the column of water which is passing the junction. One more imperfection in traps may be named. The experiments of Dr Fergus have shown that the water in traps will allow gases to pass through by absorbing the gas on one surface and giving it off at the other. It is improbable that this action occurs to such an extent as to be dangerous by permitting the transfer of disease germs from one to the other side. Apart from any risk of this kind, however, it is clear that a trap is open to so many possibilities of failure as to form a very insufficient barrier between the air of a room and the foul air of a sewer. Nevertheless the practice was until very lately almost universal, and is still far from uncommon, of connecting closets, sinks, and

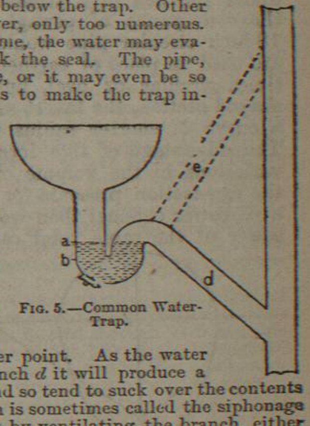

Fig. 5.—Common Water-Trap.

even bedroom basins with common sewers by a continuous system of piping, in which the only safeguard against the entry of sewer gas is a single trap close to each sink or basin. This means that sewer gas, charged with the infection of a whole community, is brought within a few inches of the atmosphere of the dwelling, ready to contaminate it whenever the trap fails from any of the causes which have been named, or whenever, by a flow of water through it, the seal is sufficiently disturbed to allow bubbles of gas to escape into the room. The remedy for this lies in having, at any convenient point on each house-drain, a disconnecting trap which separates the house system from the sewer, and so establishes what may be called an outer line of defence. Any accidental leakage of sewer gas through it then does no more than cause a comparatively slight pollution of the air within the house-drains, and if these are well ventilated the effects of this are insensible. At each individual basin or other fitting a trap is still required, but its function is now merely to shut out the air of the house-drains from the rooms, and, as the air of the house-drains is no longer polluted by connexion with the sewers, the occasional failure of this function is a matter of comparatively small moment. Further, the disconnecting trap on the house-drain furnishes a convenient place of access for fresh air; and the ventilation is completed by carrying the highest point of each soil-pipe or waste-pipe up to the level of the roof and leaving it open there. This arrangement will be understood by reference to fig. 6, which shows a soil-pipe, open at its upper end, discharging into a house-drain in which there is a disconnecting trap provided with an open grating for the entry of air. The soil-pipe is ventilated by a current of air which (usually if not always) flows upwards. This not only dilutes any gases that are produced in the pipe, but quickly oxidizes any foul matter that may adhere to the sides. Care must be taken to avoid having the upper end of the pipe open near windows or under eaves. In the figure the branch leading to a water-closet is ventilated by a pipe carried into an upper part of the soil-pipe; this is scarcely necessary if the branch be short. Another construction is to carry a distinct ventilating pipe up from the top of the branch to a point above the roof; and where several fittings discharge into one soil-pipe, the same ventilating pipe may be made to serve for all. An example of the latter arrangement is shown in fig. 10.

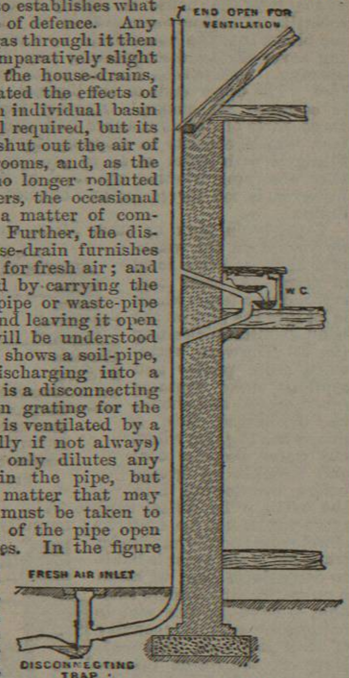

Fig. 6.—House-Drain properly disconnected from sewer, and ventilated.

The form of disconnecting trap shown in fig. 6 is that of Mr W. P. Buchan of Glasgow, who has done excellent service to the cause of sanitary reform by practising and advocating the disconnexion and ventilation of house-drains and soil-pipes. The same trap is shown to a larger scale in fig. 7, where it appears imbedded in concrete and covered by a built manhole, which gives access to the trap in case of its becoming choked. The manhole may have an open grating at the top; or the top may be closed by a solid plate (if a grating there be for any reason inadmissible), in which case a ventilating shaft is carried from the manhole to some other opening. Fig. 7 shows such a shaft leading to a grating which is placed vertically in a neighbouring wall. Among other good forms of disconnecting trap, more or less like Buchan's, mention may be made of Weaver's, Potts's, and Hellyer's.

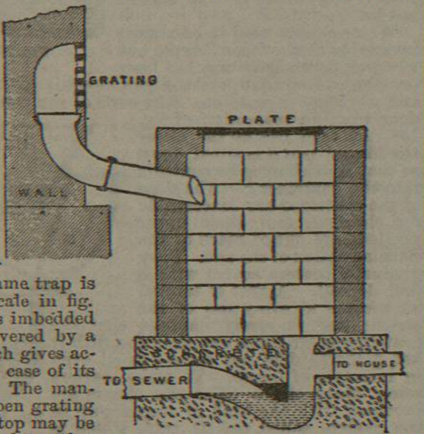

Fig. 7.—Buchan Trap and Manhole, with ventilating grating in wall.

An arrangement of double disconnecting trap is illustrated in fig. 8. Any sewer gas forcing the trap next the sewer is still kept back by the upper trap and will escape by a grating or open ventilating shaft which enters at A, while air to ventilate the house-drain enters the upper trap from the manhole. This arrangement no doubt gives more absolute protection than a single trap of the kind already described, but it is probable that (except in cases where the sewers are very foul and liable to frequent excess of pressure) the advantage is so slight as to be more than counterbalanced by the greater liability to accidental stoppage and greater complexity which this arrangement entails.

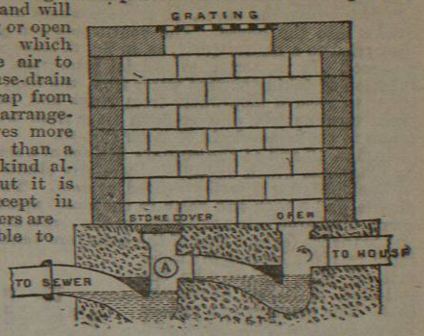

Fig. 8.—Double Disconnecting Trap.

The extent to which it is permissible or advisable in practice to allow several fittings to discharge into a single waste-pipe or soil-pipe will vary in different cases. We can recognize a broad distinction between sewage from closets and urinals, liable to the most dangerous taint should disease occur within the house, and the comparatively innocuous sewage that comes from basins, baths, and sinks. Some sanitarians go so far as to advise that these two classes of sewage should be kept absolutely apart within the house, by the use of a complete double system of house drain-pipes. This, however, is an extreme measure; no reasonable objection can be urged against the discharge into a water-closet soil-pipe of water from a bath or washhand basin in the same room, except perhaps that if the soil-pipe is of lead its corrosion is hastened by hot water; and the additional flushing which the soil-pipe so receives is a distinct advantage. But to connect a water-closet soil-pipe with sinks and basins in other apartments is to multiply possibilities for the spread of disease within the house, and it is strongly advisable to convey the waste from them by a separate pipe, protected from the sewer by a disconnecting trap of its own with a grating open to the air. This applies with special force to the washhand basins that are often fixed in bedrooms and dressing-rooms. Nothing could be more dangerous than the usage—of which many good houses still furnish instances—of multiplying these conveniences without regard to the risk they involve, and making this risk as great as possible by placing each in direct communication through an ordinary trap with the soil-pipe, itself perhaps unventilated and provided with no disconnexion from the sewer. Even when the drain or soil-pipe is ventilated and disconnected from the sewer, no bedroom basin should, under any circumstances, be allowed to discharge into it without first passing a separate open trap. On the other hand, a bedroom basin may be made perfectly safe by leading its waste-pipe (trapped under the basin in the usual way) into an open-air channel which communicates with the sewer by a surface-trap or gully outside the house (fig. 9). Similar treatment should be adopted in the case of pantry and scullery sinks. Under most plumbing fixtures it is usual to place a safe-tray to receive any water accidentally spilt. The discharge pipes from these trays are sometimes, but very objectionably, led into the waste-pipe or soil-pipe below the fixture. The proper method of providing for the discharge of water spilt into the safe-tray is to lead a pipe from it through the wall and allow it to end in the open air (fig. 10, where each of the safe-tray drains is marked "waste-pipe"); a flap valve fixed on the end will serve if need be, to keep out draught.

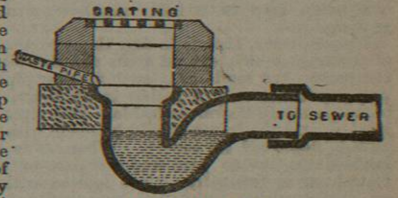

Fig. 9.—Open Trap.

Overflow-pipes from cisterns used for dietetic purposes should be led, in the same way, into the open air and not into soil-pipes or waste-pipes (fig. 10). Traps on them cannot be depended on to remain sealed, and any connexion of an overflow-pipe with a soil-pipe would result in allowing foul air from the pipe to diffuse itself over the surface of water in the cistern—a state of things peculiarly likely to cause pollution of the water. When a cistern is used only for water-closet service, its overflow-pipe may properly be led into the basin of the closet.

Rain-pipes, extending as they do to the roof, are sometimes used to serve as ventilating continuations of soil-pipes and waste-pipes. The practice is open to serious objection, for it discharges the drain air just under the eaves, at a place where air is generally being drawn into the house. The ventilating end of a soil-pipe should be carried to a higher level, as in fig. 6, clear of the lower edge of the roof. It is better to restrict rain-pipes to their legitimate function of taking surface water from the roof, or at most to allow them to receive slop-water from sinks and basins, and to make them terminate in or over open traps from which a connexion is taken to the house-drain or sewer (fig. 9).

In figs. 10 and 11 the sanitary fittings of a small house are shown by diagrams, which should be carefully studied as exemplifying a well-arranged system. Two closets, and a bath and basin in the closet apartment, discharge into a soil-pipe on the right, and the branches (except that of the basin) are ventilated by pipes leading to a separate air pipe, which, like the soil-pipe, is carried above the roof. The overflow of a cistern which supplies bath, basin, and boiler is carried out to the open air, and so are the waste-pipes of the leaden safe-trays. A separate cistern supplies each water-closet, and its overflow opens into the closet basin. A rain-pipe (in the middle of the figure)

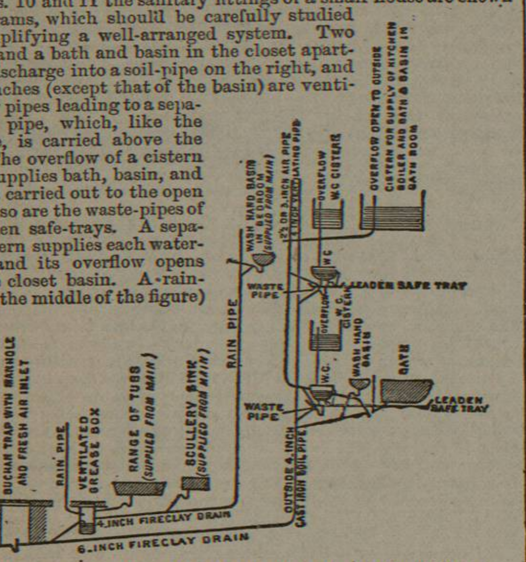

Fig. 10.—Diagram Section of the Drains and Fittings of a Small House.

receives a bedroom basin waste, and leads by a 4-inch drain to a ventilated grease-box, into which the scullery sink and wash-tubs and another rain-pipe also discharge. Finally, the whole system is protected by a Buchan trap in a built manhole, which is covered with a grating.

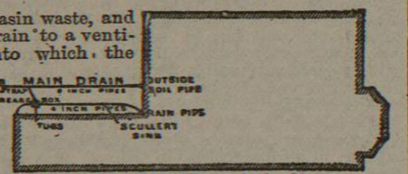

Fig. 11.—Plan of the Drains in fig. 10.

House-drains, that is to say, those parts of the domestic system of drainage which extend from the soil-pipes and waste-pipes to the sewer, are made of glazed fireclay pipes, generally 6 inches but sometimes only 4 inches in diameter. A larger size than 6 inches is rarely if ever desirable. The pipes are spigot-and-faucet-jointed, and the joints should be made with cement in the manner already described for sewers. When, as is often unavoidable, the house-drain has to pass under a part of the house, or to come from back to front, iron pipes jointed with lead and coated with an anti-corrosive compound are preferred to fireclay pipes, as giving a better security against the production of leaks by the settling of the soil and other causes. Soil-pipes, when carried down inside the house, are of either lead or iron; when outside the house they are usually of iron. An outside soil-pipe is obviously preferable to an inside one; if the arrangement of the building makes an inside soil-pipe necessary, care must be taken that it shall be easily accessible for inspection at all parts of its length. The usual diameter is 4 inches. For the sake of good ventilation it is desirable to continue the soil-pipe to a point above the roof without reduction of diameter rather than apply a smaller ventilating pipe. Amongst reasons for ventilation one remains to be mentioned,—that, owing to the corrosive action of sewer gas, the life of the soil-pipe is greatly shortened if provision for the free circulation of air be wanting or insufficient. A closed soil-pipe becomes in time pitted with holes, especially in the upper parts of its length.

Defective joints in soil-pipes and waste-pipes, particularly where they connect with drains, closet-basins, sinks, &c., are another frequent cause of leakage. Any want of air-tightness in drains or soil-pipes within a dwelling leads to the pollution of the air, not merely by diffusion, but by an actual in-draught, for generally the air of the house has its pressure reduced by chimney draughts to a value slightly lower than that of the air outside. The house, in fact, ventilates itself by drawing in air from the pipe at any hole, a fact which may easily be demonstrated by holding the flame of a taper near the hole.

Various experimental methods are used of detecting such leaks as would admit foul air to the dwelling. Of these the best is the "smoke test." It consists of filling the house-drain, soil-pipes, and waste-pipes with a dense and pungent smoke, any escape of which into the house is readily observed by eye and nose. A quantity of cotton-waste soaked in oil is lighted, and its fumes are blown into the house-drain by a revolving fan, at the ventilating cover of the disconnecting trap, or at any other convenient opening. Smoke soon fills the pipes, and begins to escape at the roof. The upper ends of the pipes are then closed, and the house is searched for smoke.[1] Another test, especially applicable to those parts of drains that are laid under houses, is the hydraulic test, which consists in stopping up the lower end of the pipe, filling it with water so as to produce a moderate pressure, and then observing whether the level of the water falls. This test, however, is too severe for any but new and very well constructed drains.

Every basin, sink, or other fitting should be separately trapped by a bend on the waste-pipe or some other form of trap. A brass cap, screwed on a ferule which is let into the pipe on the bend, facilitates cleaning (fig. 5). The warm waste-water from pantry and scullery sinks contains much grease, and should be discharged into a grease box (fig. 12) where the water becomes cool and deposits its grease before overflowing into the drain. To collect surface water from laundry floors, areas, court-yards, &c., an open trap or gully is used. Fig. 9 shows a simple and good form of open trap; but if the water is liable to carry down sand or earth a gully (fig. 13) is more suitable. Even in this simple fitting a remarkable ingenuity of error has been displayed. Many of the forms favoured by builders are bad either because of an insecure seal, a narrow outlet, or a tendency to gather filth. One in particular, the well-known "Bell" trap, is an example of nearly everything a trap should not be.

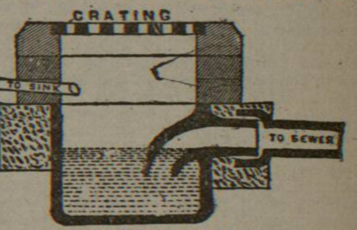

Fig. 12.—Grease Trap.

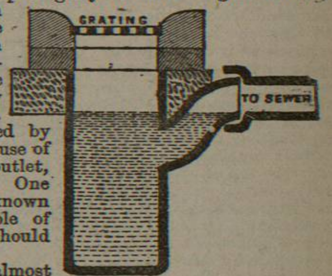

Fig. 13.—Gully-Trap.

Water-closets used to be almost invariably of the "pan" type, but wherever sanitary reform has been preached to any purpose the pan closet is giving place to cleaner and wholesomer patterns. The evils of the pan closet will be evident from an inspection of fig. 14. At each use of the closet the hinged pan *a* is tilted down so that it discharges its contents into the container *b*. The sides of the container are inaccessible for cleaning, and their upper portions are out of reach of the flushing action of the pan. They gradually become coated with a foul deposit. A gust of tainted air escapes at every use of the closet; and it rarely happens that the container is air-tight, and that the filth it has gathered does not cause a smell even in intervals of disuse. To make matters worse, many of the older pan closets are provided with the kind of trap shown in the sketch, called the D trap, which is also liable to become a gathering place for filth. Even with an ordinary trap, however, the pan closet remains so bad that its use is to be strongly condemned.

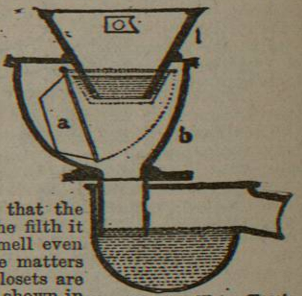

Fig. 14.—Pan Water-Closet.

A much better closet is the valve or Bramah closet, an excellent example of which by Frew of Perth is shown in fig. 15. The basin is kept partly full of water by a ground gun-metal valve tightly pressed up against a conical seat at the basin's foot. The chamber below is only large enough to allow the valve to turn down; it cannot collect much foul matter and may be ventilated by a separate pipe. A trapped overflow prevents the basin from being overfilled. The whole closet is trapped by an ordinary bend on the soil-pipe, which is not shown in the figure. The volume of water in the basin is much greater than in pan closets, where the height is limited by the overflow which occurs round the lip of the pan. In some closets of this kind the valve is placed at the side, and, when closed, lies nearly vertical. In another type of valve closet (Jennings's) the valve is a conical plug, pressed vertically down on a seat at the side.

[1] A novel plan of making the smoke test has lately been introduced, in which smoke is given off by a "smoke rocket" or cake of slowly combustible compound which is lighted and placed in the drain.

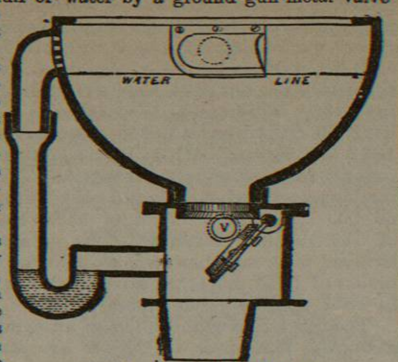

Fig. 15.—Bramah Water-Closet.

Washout closet.

Valve closets can be made fairly effective and satisfactory from a sanitary point of view; but a much cheaper and certainly not less excellent type of closet is the "washout," an example of which (the "National") is shown in fig. 16. (Another washout closet, by Doulton, appears in fig. 6.) These are now made in a great variety of good forms, sometimes of a single piece of white stoneware. They combine cheapness and simplicity with a degree of sanitary perfection that is probably not reached by the most expensive closets of the kinds already named. They have no working parts; the closet is cleansed after use simply by the flush of water, which sweeps everything before it. The flush must of course be good: a 1½-inch service pipe from a cistern not less than 5 feet above the closet will do well. In some recent designs the cistern is a box at the back of the seat with a wide oval mouth leading from it to the flushing rim of the pan: this gives a good flush although the cistern is low. A feature of construction which may be strongly recommended is to leave the closet entirely open for inspection and cleaning, instead of concealing it in a wooden case. The seat then generally rests on iron brackets projecting from the wall, and can be raised on hinges at the back, so that the pan may be used as a urinal or slop-sink without the risk of fouling. Another good type of closet, sharing with the washout the advantage of having no mechanical parts, is the "hopper," illustrated in fig. 17 (Dodd's Hopper). In all these closets the horn marked V is for attaching a ventilating pipe.

Fig. 16.—Washout Water-Closet.

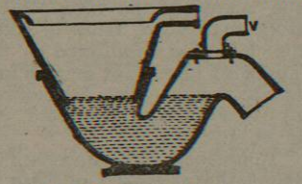

Fig. 17.—Hopper Closet.

For the supply of water to a closet a separate cistern is desirable, especially when water for dietetic purposes is liable to be drawn from the main cistern (instead of being taken direct from the water service pipe, which is better). It would seem needless to add, were it not that such faults are common, that no cistern—unless it be exclusively used for water-closet supply—should be placed in the same room with or just under a water-closet, and that the room itself should be well lighted, well ventilated, and well shut off from bedrooms. To prevent flushing of closets from being imperfect through carelessness, many plans have been devised for ensuring that once the flow of water is started it will continue until a given volume has been discharged. One of the best of these is the arrangement of siphon flush sketched in fig. 18: when the valve *a* is opened the downrush of water starts the siphon *b* into action, and even should *a* be then closed the flow continues until the water-level falls to *c*, when air is admitted and the siphon ceases to act. The air-pipe *c* is cut to give the desired volume.

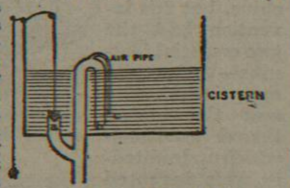

Fig. 18.—Water-Closet Cistern with Siphon Flush.

As regards house-drainage generally, the points of chief importance may be briefly summed up as follows:—(1) the use of one or more disconnecting traps to shut off sewer gas from the whole system of house-drains and pipes; (2) the thorough ventilation of house-drains, soil-pipes, and branches, by providing openings through which air can enter at the foot and escape at the top; (3) the discharge of all sinks, basins, &c., other than water-closet fittings, and especially of fixed bedroom basins, into open traps in the open air; (4) the direct discharge of cistern overflows and safe-trays into the open air; (5) the use of cleanly and well-designed closets, basins, &c., each sealed by an ordinary bent trap; (6) the use of separate service cisterns for water-closets.

It may seem superfluous to add that the system of pipes must provide a rapid and effective carriage of all sewage to the sewer, and must be water-tight and air-tight. During the last five years, however, it has been proved, by examination of the best houses in London, that it is no uncommon case for a house to be so completely without effective connexion with the sewer that all its own sewage sinks into the soil under the basement; and about 75 per cent. of the houses inspected have failed to pass the "smoke test."

In this connexion mention should be made of the system of co-operative house-inspection originated by the late Prof. Fleeming Jenkin. The Edinburgh Sanitary Protection Association was founded by him in 1878 to carry out the idea that the sanitary fittings of a house should be periodically submitted to examination by an expert, and that householders should combine to secure for this purpose the continuous service of an engineer able to detect flaws, to advise improvements, and to superintend alterations. The Edinburgh association soon justified its existence by discovering, in the houses of its members, a state of things even worse than students of sanitary science had imagined possible. Similar associations are now doing excellent work in London, Glasgow, and many other large towns.

Space admits of only a very brief mention of those systems of sewerage in which excreta are not removed by the aid of water. The dry-earth system, introduced by the Rev. H. Moule, takes advantage of the oxidizing effect which a porous substance such as dry earth exerts by bringing any sewage with which it is mixed into intimate contact with the air contained in its pores. A discharge of urine and fæces is quickly and completely deodorized and absorbed when covered with a small quantity of dry earth; and the same soil, if exposed to the air and allowed to dry, may be used over and over again for the same purpose. Even after soil has been several times used, however, its value as manure is not so great as to pay for its transport to any considerable distance; and for this reason, as well as from the fact that it leaves other constituents of sewage to be dealt with by other means, the system is of rather limited application. So far as it goes it is excellent, and where there is no general system of water-carriage sewerage, or where the water-supply is small or uncertain, an earth-closet will, in careful hands, give perfect satisfaction. Numerous forms of earth-closet are sold in which a suitable quantity of earth is automatically thrown into the pan at each time of use. Arrangements of this kind are, however, not necessary to the success of the system; a box filled with dry earth and a hand scoop will answer the purpose not less effectively. Ashes are sometimes substituted for or mixed with the dry earth and powdered charcoal is also used.

The most primitive method of dealing systematically with excreta is to collect the discharges directly in a vessel which is either itself carried to the country, and its contents applied to the land, or is emptied into a more portable vessel for that purpose. In Japan, for example, in spite of the difficulty of transport over bad roads and by human labour, the latter plan is universally followed: the land and the people have in fact performed for centuries what may be called a complete cycle of operations. The agricultural return is so good that farmers pay for leave to remove excrement, and householders look to their discharges as a source of income. The plan, although carried out in the roughest manner, appears to involve fewer sanitary drawbacks than might be expected; but the smells from privies and carts, and, above all, from the process of emptying by ladle, are a nuisance which no Western community would tolerate. A simple pail system, in which the sewage is collected and removed in the same vessel, has been used at Rochdale; another, with an absorbent lining in the pails, at Halifax. A plan much used in Continental cities is to collect excrement in tight vaults, which are emptied at intervals into a tank cart by a suction pump or injector. A more recent pneumatic system is that of Liernur, applied at Amsterdam, where sewage reservoirs at individual houses are permanently connected with a central reservoir by pipes, through which the contents of the former are sucked by exhausting air from the reservoir at the central station. A similar plan has been tried at Lyons and Paris by M. Berlier.

References.—The blue-book literature of sewage disposal is very voluminous. Special reference should be made to the *Reports of the Rivers Pollution Commissioners*, from 1866: *Report of the Referees on Metropolitan Main Drainage*, 1857; *Reports of the Commission on the Sewage of Towns*, 1858–1865; *Reports of Select Committees of the House of Commons*, 1862 and 1864; *Reports of the British Association Committee on the Treatment and Utilization of Sewage*, 1869–1876; *Report of the Birmingham Sewage Inquiry Committee*, 1871; *Reports of the Local Government Board*; *Reports of the Royal Commission on Metropolitan Sewage Discharge*, 1884 (the second and final report contains a valuable historical résumé of the subject). See also the following books:—Corfield, *Treatment and Utilization of Sewage*, 1871; Burke, *Handbook of Sewage Utilization*, 1873; Robinson and Melliss, *Purification of Water-carried Sewage*, 1877; Robinson, *Sewage Disposal*, 1882; J. Bailey-Denton, *Intermittent Downward Filtration*, 2d ed., 1885. Engineering details of sewerage are given in Baldwin Latham's *Sanitary Engineering*, 2d ed., 1878; and particulars of the drainage of individual towns will be found in numerous papers in the *Minutes of Proceedings* of the Institution of Civil Engineers. The domestic aspect of sewerage has been treated by E. Bailey-Denton, *Handbook of House Sanitation*, 1882; W. P. Buchan, *Plumbing and House Drainage*, 4th ed., 1883; W. Eassie, *Healthy Houses*, 1876; Gerhard, *House Drainage*, New York, 1882; Waring, *Sanitary Drainage of Houses and Towns*, Boston, 4th ed., 1883; F. Jenkin, *Healthy Houses*, 1878; and many other writers. (J. A. E.)

SEWIN, or SEWEN. See SALMONIDÆ, vol. xxi. p. 222.

SEWING MACHINES. The sewing machine, as is the case with most mechanical inventions, is the result of the efforts of many ingenious persons, although it would appear that the most meritorious of these worked in entire ignorance of the labours and successes of others in the same field. Many of the early attempts to sew by machinery went on the lines of imitating ordinary hand-sewing, and all such inventions proved conspicuous failures. The method of hand-sewing is of necessity slow and intermittent, seeing that only a definite length of thread is used, which passes its full extent through the cloth at every stitch, thus causing the working arm, human or otherwise, to travel a great length for every stitch made, and demanding frequent renewals of thread. The foundation of machine-sewing was laid by the invention of a double-pointed needle, with the eye in the centre, patented by Charles F. Weisenthal in 1755. This device was intended to obviate the necessity for inverting the needle in sewing or embroidering, and it was subsequently utilized in Heilman's well-known embroidery machine.

Many of the features of the sewing machine are distinctly specified in a patent secured in England by Thomas Saint in 1790, in which he, *inter alia*, describes a machine for stitching, quilting, or sewing. Saint's machine, which appears to have been intended principally for leather work, was fitted with an awl which, working vertically, pierced a hole for the thread. A spindle and projection laid the thread over this hole, and a descending forked needle pressed a loop of thread through it. The loop was caught on the under side by a reciprocating hook; a feed moved the work forward the extent of one stitch; and a second loop was formed by the same motions as the first. It, however, descended within the first, which was thrown off by the hook as it caught the second, and being thus secured and tightened up an ordinary tambour or chain stitch was formed. Had Saint hit on the idea of the eye-pointed needle his machine would have been a complete anticipation of the modern chain-stitch machine.

The inventor who first devised a real working machine was a poor tailor, Barthélemy Thimonier, of St Étienne, who obtained letters patent in France in 1830. In Thimonier's apparatus the needle was crocheted, and descending through the cloth it brought up with it a loop of thread which it carried through the previously made loop, and thus it formed a chain on the upper surface of the fabric. The machine was a rather clumsy affair, made principally of wood, notwithstanding which as many as eighty were being worked in Paris in 1841, making army clothing, when an ignorant and furious crowd wrecked the establishment and nearly murdered the unfortunate inventor. Thimonier, however, was not discouraged, for in 1845 he twice patented improvements on it, and in 1848 he obtained both in France and the United Kingdom patents for further improvements. The machine was then made entirely of metal, and vastly improved on the first model. But the troubles of 1848 blasted the prospects of the resolute inventor. His patent rights for Great Britain were sold; a machine shown in the Great Exhibition of 1851 attracted no attention, and Thimonier died in 1857 unfriended and unrewarded.

The most important ideas of an eye-pointed needle and a double thread or lock-stitch are strictly of American origin, and that combination was first conceived by Walter Hunt of New York about 1832–34. Hunt reaped nothing of the enormous pecuniary reward which has been shared among the introducers of the sewing machine, and it is therefore all the more necessary that his great merit as an inventor should be insisted on. He constructed a machine having a vibrating arm, at the extremity of which he fixed a curved needle with an eye near its point. By this needle a loop of thread was formed under the cloth to be sewn, and through that loop a thread carried in an oscillating shuttle was passed, thus making the lock-stitch of all ordinary two-thread machines. Hunt's invention was purchased by a blacksmith named Arrowsmith, and a good deal was done towards improving its mechanical details, but no patent was sought, nor was any serious attempt made to draw attention to the invention. After the success of machines based on his two devices was fully established, Hunt in 1853 applied for a patent; but his claim was disallowed on the ground of abandonment. The most important feature in Hunt's invention—the eye-pointed needle—was first patented in the United Kingdom by Newton and Archbold in 1841, in connexion with glove-stitching.

Apparently quite unconscious of the invention of Walter Hunt, the attention of Elias Howe, a native of Spencer, Mass., was directed to machine-sewing about the year 1843. In 1844 he completed a rough model, and in 1846 he patented his sewing machine (fig. 1). Howe was thus the first to patent a lock-stitch machine, but his invention had the two essential features—the curved eye-pointed needle and the under-thread shuttle—which undoubtedly were invented by Walter Hunt twelve years previously. Howe's invention was sold in England to William Thomas of Cheapside, London, a corset manufacturer, for £250. Thomas secured in December 1846 the English patent in his own name, and engaged

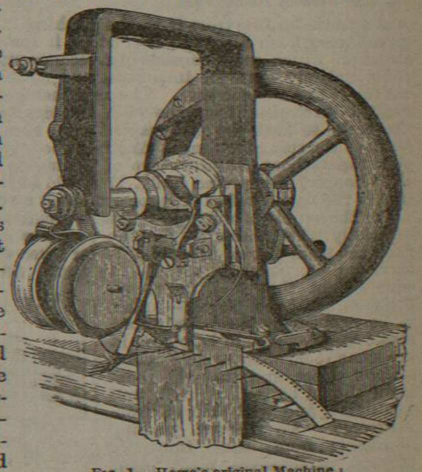
FIG. 1.—Howe's original Machine.

Howe on weekly wages to adapt the machine for his manufacturing purposes. The career of the inventor in London was chequered and unsuccessful; and, having pawned his American patent rights in England, he returned in April 1849 in deep poverty to America. There in the meantime the sewing machine was beginning to excite public curiosity, and various persons were making machines which Howe found to trench on his patent rights. The most prominent of the manufacturers, if not of inventors, ultimately appeared in the person of Isaac Merritt Singer, who in 1851 secured a patent for his machine (fig. 2), and immediately devoted himself with immense energy to push the fortunes of the infant industry. Howe now became alert to vindicate his rights, and, after regaining possession of his pawned patent, he instituted suits against the infringers. An enormous amount of litigation ensued, in which Singer figured as a most obstinate defendant, but ultimately all makers became tributary to Elias Howe. It is calculated that Howe received in the form of royalties on machines made up to the period of the expiry of his extended patent—September 1867—which was also the month of his death, a sum of not less than two millions of dollars.

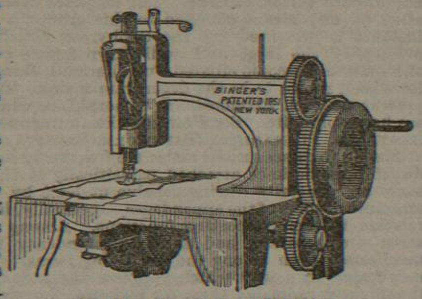

FIG. 2.—Singer's original Machine.

The practicability of machine-sewing being demonstrated, inventions of considerable originality and merit followed in quick succession. One of the most ingenious of all the inventors—who worked also without knowledge of previous efforts—was Mr Allan B. Wilson. In 1849 he devised the rotary hook and bobbin combination, which now forms the special feature of the Wheeler & Wilson machine. Mr Wilson obtained a patent for his machine, which included the important and effective four-motion feed, in November 1850. In February 1851 Mr William O. Grover, tailor, of Boston, patented his double chain-stitch action, which formed the basis of the Grover & Baker machine. At a later date, in 1856, Mr James A. E. Gibbs, a Virginia farmer, devised the improved chain-stitch machine now popularly known as the Willcox & Gibbs. These together—all American inventions—form the types of the various machines now in common use. Several thousands of patents have been issued in the United States and Europe, covering improvements in the sewing machine; but, although the efficiency of the machine has been greatly increased by numerous accessories and attachments, the main principles of the various machines have not been affected thereby.

In machine sewing there are three varieties of stitch made,—(1) the simple chain or tambour stitch, (2) the double chain stitch, and (3) the lock stitch. In the first variety the machine works with a single thread; the other forms use two, an upper and an under thread.

The structure of the chain stitch is shown in fig. 3. The needle first descends through the cloth, then as it begins to ascend the friction of the thread against the fabric is sufficient to form a small loop into which the point of a hook operating under the cloth plate enters, expanding and holding the loop while the needle rises to its full height. The feed then moves the fabric forward one stitch length, the hook with its loop is also projected so that when next the needle descends its loop is formed within the previous loop. The hook then releases loop No. 1, seizes and expands loop No. 2, and in so doing draws up the previous loop into a stitch, chain-like on the under side but plain on the upper surface of the fabric. The seam so made is firm and elastic, but easily undone, for if at any point a thread is broken the whole of the sewing can be readily run out backwards by pulling the thread, just as in crochet work. To a certain extent this imperfection in the chain-stitch machine is overcome in the Willcox & Gibbs machine, in which each loop is, by means of a rotating hook, twisted half a revolution after it has passed through its predecessor.

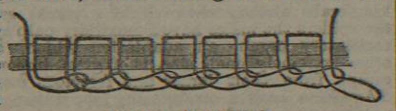
FIG. 3.—Chain Stitch.

The double chain stitch is made by machines associated with the name of Grover & Baker. The somewhat complicated course of the threads in this stitch is shown in fig. 4. The under thread in this machine is supplied from an ordinary bobbin and is threaded through a circular needle of peculiar form. The machine is wasteful of thread, and the sewing forms a knotted ridge on the under side of the fabric. Except for special manufacturing and ornamental purposes the machine is now in little use.

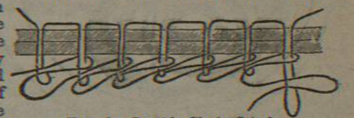
FIG. 4.—Double Chain Stitch.

The lock stitch is that made by all ordinary two-thread sewing machines, and is a stitch peculiar to machine sewing. Its structure is, as shown in fig. 5, very simple, and when by proper tension the threads interlock within the work the stitch shows the same on both sides and is very secure. When, however, the tension on the upper thread is weak, the under thread runs along the surface as at *b*, held more or less tightly by the upper loops. It will be seen that to make the chain stitch the under thread has to be passed quite through the loop of the upper thread. That is done in two principal ways. By the first plan a small metal shuttle, holding within it a bobbin of thread, is carried backward and forward under the cloth plate, and at each forward movement it passes through the upper thread loop formed by each succeeding stroke of the needle. Such is the principle devised by Hunt, introduced by Howe, and improved by Singer and many others. The second principal method of forming the lock stitch consists in seizing the loop of the upper thread by a rotating hook, expanding the loop and passing it around a stationary bobbin within which is wound the under thread. The method is the invention of Mr A. B. Wilson, and is known generally as the Wheeler & Wilson principle. The rotary hook seen at *b*, fig. 6, is so bevelled and notched that it opens and expands the upper thread loop, causing it quite to enclose the bobbin of under thread, after which it throws it off and the so-formed lock stitch is pulled up and tightened either by an independent take-up motion as in recent machines, or by the expansion of the next loop as in the older forms. The bobbin A, lenticular in form, and its case B, fig. 6, fit easily into a circular depression within the hook, against which they are held by the bobbin holder *a*, fig. 6.

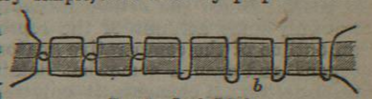

FIG. 5.—Lock Stitch.

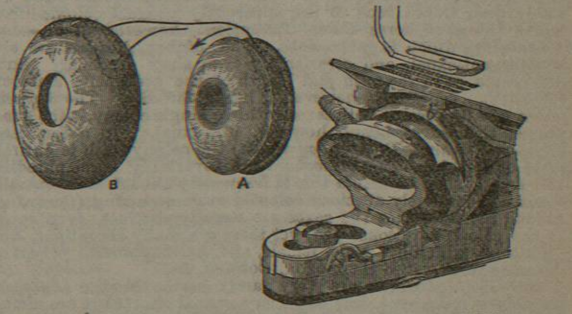

FIG. 6.—Rotary Hook, Bobbin, and Bobbin Case (Wheeler & Wilson Machine).

Intermediate between the shuttle and the rotary-hook machines is the new oscillating-shuttle machine introduced by the Singer Co. The shuttle is hook-formed, not unlike the Wilson hook, and it carries within it a capacious circular bobbin of thread *h*, fig. 7. This shuttle is driven by an oscillating driver *db* within an annular raceway *a a*, and, instead of revolving completely like the Wilson hook, it only oscillates in an arc of 150°, so far as serves to catch and clear the upper thread. The oscillating-