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DWELLING HOUSES

THEIR

SANITARY CONSTRUCTION AND ARRANGEMENTS.

By the same Author.

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SANITARY CONSTRUCTION

AND

ARRANGEMENTS

BY

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PHILADELPHIA
PRESLEY BLAKISTON, 1012 WALNUT STREET
1880

NOTE.

The following chapters were delivered as a Course of Cantor Lectures before the Society of Arts. The lectures were largely illustrated by specimens borrowed from the Parkes Museum of Hygiene, at University College, and the illustrations at the end of this book are a selection from those in the catalogue of that museum.

It is hoped that the book may be useful as a short and practical exposition of the means by which dwelling houses may be made wholesome.

W. H. C.

10 *Bolton Row*, *Mayfair*, *W*.
September, 1880.

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DWELLING-HOUSES

THEIR SANITARY CONSTRUCTION AND ARRANGEMENTS.

CHAPTER I.

Situation and Construction of Houses.

It is only necessary for me to make a few introductory remarks about climate. Although few persons can choose what part of the world they will live in, a considerable number are able to decide in what part of the country they will reside. Other things being equal, the nearer a place is to the sea, the more equable is the climate, and the further inland the place is, the more is the climate one of extremes; so that those who wish for a moist, equable climate, with warm winters and warm nights, will choose a place by the seaside; while those who wish for a more bracing atmosphere will go further inland. In England, too, as is well-known, there is considerable difference between the climate at various parts of the seaboard. Thus, the western coast, being exposed to the winds which pass over the Atlantic, and to the action of the moist, warm, air which passes over the course of the Gulf Stream, has a warm, moist atmosphere, and a heavy rainfall; while the eastern coast, which is swept by winds that have passed across Siberia and Russia, and have only the narrow strip of

German Ocean to pass over before they reach our coast, has a dry, bleak, and comparatively cold climate.

For the same reason, too, the exposition of a house, or the way in which it faces, is a matter of great importance in this climate, as is well known; a southern exposition, for example, being warm and genial, whilst an eastern one is just the reverse.

In the neighbourhood of forests, the air is damp during a great part of the year, from the enormous amount of evaporation that takes place from the leaves of the trees, and Humboldt tells us that the large forests on the banks of the Amazon are perpetually covered with mist. Other things being equal, a bare open country is drier and hotter than a well-wooded one.

I will divide the soils, for sanitary purposes, into two kinds—pervious and impervious; those that allow water to pass freely through them, and those that do not. Pervious soils are such as gravel, sand, and the less compact and softer limestones, which allow water to pass through their interstices, and chalk, in which the water for the most part travels through the fissures; and the typical impervious ones, such as the various clays, mostly named from the localities where they are best known, as the London clay, Oxford clay, Kimmeridge clay. Most of the metamorphic rocks and the hard limestones are non-porous, but have a multitude of crevices, through which the water finds its way. In the former case the water which falls on the surface passes readily through the soil, until it comes to some impervious stratum below, over which it accumulates and along which it flows, until it either finds outlet at the surface of the ground, where the impervious stratum crops out, or until it reaches the nearest watercourse; so that above the impervious layer, which has arrested its progress through the rocks, there is a stratum of water of a depth which will vary with a variety of circumstances—a stratum which can be reached from the surface of the ground by digging wells down to it. This water we call the "subsoil" water, or the ground water (*grundwasser*). In some instances, the impervious stratum just spoken of is placed in such a manner as to prevent the escape of the subsoil water at all, in which case the soil is said to be water-logged. The water which falls on the impervious soils, on the other hand, does not sink into the ground, but remains on the surface, or runs off if there be a suitable incline, and so such soils are necessarily damp. The diseases that are prevalent upon the pervious soils are enteric (typhoid) fever, and cholera during epidemics of that disease, diseases, in fact, the poisons of which are chiefly communicated by means of drinking water; and the readiness with which the subsoil water just mentioned can be contaminated by the percolation into it of foul matters from the refuse of habitations, combined with the fact that people who live on such soils, as a rule, drink water from wells dug in them, no doubt accounts for the prevalence of those diseases.

On impervious damp soils, on the other hand, consumption, the great plague of our climate, which kills more than half as many people as all the communicable fevers put together, is prevalent, and so are lung diseases of various kinds, rheumatism, and, under special circumstances, ague. It has been clearly shown that dampness of the soil under the houses is one of the factors in the production of consumption. Dr. George Buchanan (see 9th report of the Medical Officer of the Privy Council) demonstrated that in every instance where the level of the subsoil water in a town had been lowered, that is to say, where the distance between the basements of the houses and the level of the water in the soil had been made greater, the death-rate from consumption had decreased—in one instance to the extent of not less than 50 per cent., so that there can be no question that it is extremely important for everyone who can to live upon a dry soil. Where then the soil is not pervious to a considerable depth below the basements of the houses, so that the level of the ground-water comes within a few feet of them, or where the soil being itself pervious, is naturally water-logged, or in the so-called impervious soils, which are, of course, all pervious to some extent, it is necessary to provide means whereby the level of the water shall be kept below a certain minimum depth from the foundations of the houses. This is done by drainage, and by a drain I mean a pipe or channel that is intended to remove the water from the soil. It must, therefore, be a pipe into which the water can get—that is to say, it must be pervious to water. The object of drains then is twofold, to carry off the surface water, and to prevent the subsoil water rising above a certain height, for as soon as it rises to the level of the drains, it finds its way into them, and is carried away to the outfall at a lower point.

Drains may, therefore, be made of stones placed together without cement, as was the case with the Cloaca Maxima, the great drain which was constructed by the second king of Rome to dry the ground around the Forum; or of brickwork, with or without mortar; or, as is very commonly the case, of pervious agricultural tiles. The surface gutters must also be mentioned in connection with the drains, and they are, of course, especially necessary on impervious soils. The ultimate destination of the drains is into the watercourses, streams, rivers, &c.

So much for natural soils; but, especially in the neighbourhood of most of our large towns, many of the houses are built upon artificial soil, or "made ground" as it is called. This made ground consists of the refuse of dust-bins, ash-pits, midden-heaps, and the like, which is shot at some place where the ground requires to be raised. It is very undesirable that houses should be built on any such made ground, at any rate for a considerable period. There is no doubt, however, that, after some time, the action of the air and water in the soil causes a slow decomposition of the organic matters in it, and renders it less objectionable as a site for building purposes. Nevertheless, no one would choose to live in a house built upon "made ground" if he could help it.

The proximity of buildings is the next matter to be considered. It is important that houses should not be too near together, as otherwise both light and ventilation are interfered with, and it is now a regulation in the metropolis that a new street shall be at least as wide as the houses on either side of it are high, and that no new street shall be less than 40 feet wide.

Having determined the site on which to build, we come next to the *foundations*. These should not be on made ground, nor on purely vegetable soil, as peat, humus, &c. Their depth is a matter which it is the architect's province to determine, and depends upon various circumstances, such as the weight they have to support. The material used must be the best concrete. The inferior kinds, made with too little lime or cement, crumble away, allow air to pass through them, and make the house unwholesome, besides endangering the structure. It is important to remark here that a house should not be built, or even its foundations laid, in frosty weather, for the work will not hold when a thaw sets in.

Basement.—The covering of the ground with some impervious material is imperative, in order that the moist air from the soil may be prevented from rising into the house. In the case of made soils, the covering of the ground should extend for some distance round the house. This covering is best made of concrete some inches thick, and should be used in all cases, whether there are any under-ground rooms or not. Such underground rooms or basement floor should be only used as cellars—not as living rooms—and should always be arched. The concrete floor may be covered with asphalte, tiles, or York paving, but wooden floors should never be used below the ground level. The walls of the house, below the level of the ground and a little above it, should be made with exceptionally good materials, and set in cement, so as to be as impervious as possible to damp. This is a matter that is very frequently lost sight of, and the walls below the level of the ground are frequently made of the worst possible materials. Being hidden from sight, it is often considered that the best materials need not be used for them. It is advisable to have a damp course in the walls all round the house, at a little distance above the ground level, whether the site be a damp one or not. This damp course may be made of asphalte, stoneware, or slate set in cement. Cement alone cannot be depended on. If such a course is not placed in the wall, moisture will rise up through the bricks by capillary attraction, and make the walls of the house damp, rendering the house itself unwholesome. The inner side of the walls in the basement floor may be advantageously made of glazed bricks or of hard black Staffordshire bricks, but no covering of any kind whatever should be placed on those walls. The money should be spent on good construction, and not on covering up bad materials. There should be a dry area all round the walls of the house outside, starting from the concrete foundations. Its width is a matter of little importance, as it is only required to ensure dryness of the walls below the level of the ground, and the ventilation of the cellars in the basement, unless, indeed, the basement rooms are inhabited, in which case, at any rate, the regulations of the Public Health Act must be complied with. This area must have proper connection with the land drains to allow of the removal of the surface water.

Walls.—The materials used for building these depend upon the locality. They may be bricks, stone of various kinds (the choice of which must be left to the discretion of the architect) or, in some parts of the country, flints. Bricks stand fire better than anything else, for the simple reason that they have been already burnt. This fact was remarkably shown in the great fire at Chicago, where the brick houses remained comparatively intact, while the granite ones were utterly destroyed. In any case the materials should be set in mortar or cement, and in wet and exposed positions the walls should be double or "hollow" walls, as they are technically termed. Occasionally, in such positions they should even be slated on the outside, or covered with glazed tiles. Walls are sometimes made of concrete, a very ancient plan, and not modern as is commonly supposed. The Romans frequently used concrete walls in their aqueduct bridges and other constructions. The cement used was of extraordinary hardness, and has, I believe never been surpassed, even if equalled, in later times. It might be called the "cement of the Romans," as the term "Roman cement" is now commonly applied to a very inferior article. In making concrete columns, the Romans adopted the practice of inserting layers of their flat bricks, which we should perhaps call tiles, at intervals, and they faced the surface with stones, generally disposed after the fashion known as *opus reticulatum*. This consisted in placing small cubical blocks of stone against the surface of the concrete, so that the sides of the exposed faces were not vertical and horizontal, but the diagonals were, thus giving the appearance of network, or of a chess-board set up on one corner.

These devices assisted greatly in protecting the structure from the weather, and from rough usuage. Such walls may also be very well faced with tiles of various kinds.

Chimney flues.—These should be as straight as possible. They should be separate from one another—a matter very often not attended to—and they are better lined with pipes, as these are much more easily cleaned, an up-draught is more readily established in them, and they completely disconnect the flue from the structure of the house, and so help to prevent destruction by fire.

It is important that the chimneys should be higher than the surrounding buildings, so that the wind may pass freely over them, and that they may not be sheltered from its action in any direction whatever. If this is not the case, there will be a down draught in the chimneys when the wind is in a certain direction, and the more the chimneys are sheltered by high buildings the the more chances there are of down draughts in them. If necessary, an iron or zinc pipe called a "tall-boy" may be placed on the top of the brickwork, to increase the length of the flue. This is sometimes even carried up adjoining buildings, and is, as a general rule better without a cowl of any kind on the top of it, as will be further explained in the next lecture.

Flooring.—Fire-proof floors are most desirable. They may be made of concrete or brick arches between iron girders, in which case there is no space between the flooring of one room and the ceiling of the room below. When timber is used, it should be dry and well-seasoned, with sound boarding and pugging, to ensure separation between the rooms, and to prevent either water leaking from the floor to the ceiling below, or air passing from the room below to that above. Good flooring evidently serves to protect the ceilings of the rooms below. Where there is space between the flooring and the ceiling, and still more especially where a wooden flooring is placed over a concrete or other foundation laid on the ground, it is necessary to provide for ventilation of the space below the flooring. This is usually done by placing a perforated iron grating, instead of a brick, here and there in the outer walls, so that air can pass freely in or out below the floors. For this purpose bricks with conical holes through them, (Ellison's patent) would no doubt be found very useful.

The Roof.—This may be constructed either of fireproof materials, or of timber, and in either case may be covered with slate or tiles, or may be thatched; copper or corrugated iron are also used. Sometimes zinc is used on account of its cheapness, but it is not a good material, as it does not last long. Lead is largely used, especially upon flat roofs, and it is valuable on account of its lasting properties. Where there are eaves, it is important that they should not drip on to the walls, but project, so as to throw the water off. Cornices and all projections should be constructed so as to throw off the rain, or it will run down the walls. If this is not done the walls will be continually damp and dirty. Rain water gutters may be made of lead or iron. They must have a sufficient fall, and shoot directly into the heads of the rain-water pipes. They should be wide enough inside to stand in, so that the snow may be cleared out. If this is not done it will accumulate, blocking up the channel, and when the thaw comes the melted snow will work its way through the tiles or slates of the roof, and injure the ceilings below.* Rain-water gutters should not be carried through the house from one side to the other, and especially not through bedrooms. Nor should they be carried, as is sometimes done, round the house inside the walls, and through the rooms. A more or less disagreeable smell is frequently noticed in rooms through which rain-water gutters pass. The rain-water pipes should also be outside the house. They should be of iron, well jointed. Galvanised iron ones are preferable ; they are only a little more expensive and last much longer. They should either discharge into rain-water tanks, which must be well ventilated, or on to the surface of the ground or area round the house. They should not be directly connected with the drains or sewers. Neither should they be placed with their hoppers or heads just below the bed-room windows, especially if they discharge into a tank. Large and high houses, especially if standing alone, require to be provided with lightning conductors. Copper ones are better than iron, and need not be so thick. They must be insulated from the walls of the house by suitable rings of some non-conducting material, and end in some moist place in the soil. In the case of an isolated house it is also a good plan to have a weather-cock on the roof, and connect that with a

* The remark as to the width of gutters does not apply to eaves-gutters.

registering apparatus in the hall. An anemometer is also useful.

Thus far about the construction of the building itself. We now come to finishing off inside. The floors should be covered with boarding—oak bees-waxed being the best, or deal, stained and varnished, may also be used. The joints are better tongued. Parquet flooring, made of teak, may be placed over the whole of the surface, the object being to ensure, as far as possible, a uniform and impervious surface, without cracks or badly made joints in which dust may accumulate. This is especially important. Either of these plans is better than the common one of covering the whole floor with a carpet or drugget; when these are used, a border of stained and varnished or polished boards, or of parquet flooring, should be left all round the room. This has the advantage that dust does not accumulate so readily in the corners, which are more easily swept and cleaned, and the carpet can be taken up at any time to be beaten without moving the furniture which is against the walls. The skirting boards of wooden floors should be let into a groove in the floor. This will serve to prevent draughts coming through, and dust accumulating in the apertures which are invariably formed by the shrinking of the joints and the skirting. Some floors, such as those of halls, greenhouses, &c., are best tiled.

Wall Coverings.—These, like the floors, are better made of impervious materials which can be washed. Tiles form an admirable wall covering, and are, moreover a permanent decoration. Various kinds of plastering, with the surface painted, form a cheap and effective wall covering. Paint containing lead should, of course, not be used, but the silicate, or the "indestructible" paints, and zinc white should be used instead of white lead. Paper as a covering for walls has the disadvantage that, unless varnished, it cannot be washed, and that the dust collects on it. For this reason, after a case of infectious disease, it is necessary as a general rule to strip the paper off the walls, whereas a painted or tiled one can be washed. Many papers, too, are coloured with arsenical paints, and seriously affect the health of the persons living in the rooms, the walls of which are covered with them. For a considerable amount of information on this subject, I would refer to a little book which has just appeared entitled "Our Domestic Poisons," by Mr. Henry Carr.

Ceilings.—For these, plastering is in most general use. It is better painted than distempered. Whitewashing, however, answers very well, and can be repeated as often as necessary. Paper should not be used for covering ceilings. If they are of wood it should be pannelled, or the joints will let dust through. The wood work generally throughout the house should be stained and varnished, polished, or painted; and generally I may sum up the principles to be followed in finishing off the inside of a house, by saying that the materials should be, as far as possible, impervious, and the surface smooth and uniform, and so disposed as to be easily cleaned, and not to collect the dust.

CHAPTER II.

Ventilation, Lighting, and Warming.

The air in our houses is rendered impure in various ways, but chiefly by our respiration, and by the products of combustion that are allowed to escape into it from lights and fires. The air that we expire contains a certain quantity of foul, or putrescent, organic matter. It is charged with moisture, and contains about five per cent. less oxygen and nearly five per cent. more carbonic acid than the air that we inspire. It is neither the diminution of oxygen nor the increase of carbonic acid in the air of rooms that is of the greatest importance to living beings, but the accumulation of foul organic matter and the excess of moisture. It is this which renders such atmospheres stuffy, and not the diminution of oxygen or the increase of carbonic acid, which are so slight as to be of little importance, even in overcrowded rooms. Nevertheless, since the increase in carbonic acid is proportional to the increase in other impurities, and since we can estimate very accurately the amount of carbonic acid in the air, the increase of carbonic acid is taken as an index of the impurity of the atmosphere. The average amount of carbonic acid in the outer air is four parts in ten thousand. Professor De Chaumont found by his experiments that, whenever the amount of carbonic acid in the air of a room exceeded the amount in the outer air by more than two parts per 10,000, the air of the room was not fresh, that is to say, that the foul organic matter in it and the excess of moisture were sufficient to make the room stuffy. Hence, two parts of carbonic acid per 10,000 of air, over and above that in the outer air, are taken as the limit of respiratory impurity. As a person breathes out, on the average, six cubic feet of carbonic acid in ten hours, it is clear that, in order that the air of the room in which he is may be kept fresh, he must have 30,000 cubic feet of air in the 10 hours, or 3,000 per hour. In this climate we cannot change the air of a room more than three or four times per hour without causing draught, and so each person ought to have from a thousand to 750 cubic feet of space, the air of which should be changed three or four times per hour respectively. The way in which this space is arranged is also a matter of some importance. For instance, the air above a certain height is of little use for purposes of ventilation if combined with too small a floor space. To take an extreme case—a man standing on a square foot of ground, with walls 3,000 feet high all round him, would be in 3,000 cubic feet of space; but it is quite obvious that he could not live in it. But, even without any enclosure at all, and without any limit as to height, it is not difficult to conceive a place overcrowded. For instance, all the inhabitants in the world, men, women, and children, could stand upon the Isle of Wight; but it is quite certain that they could not live there, even if it were only for the want of air. So it is usual, in estimating cubic space, to disregard the height above twelve feet. It is also obviously of importance that the floor space should be properly distributed; but, about this, so far as dwelling-houses are concerned, there is no need to enter into particulars. We are not able to insist on anything like 1,000 or 750 cubic feet of space in all instances, and amounts varying down to as low as 300 cubic feet per individual are adopted. In the case of a family living in one room, which is so small as to afford less than 300 cubic feet per individual, it is usual to consider that the limit of overcrowding which should be allowed by law has been reached. We cannot have, as a general rule, rooms so large that the air does not require changing while we are in them. Thus, for instance, a person in a bedroom for seven hours consecutively requires about 21,000 cubic feet of air if the atmosphere is to be kept fresh. Supposing him to have this without change of air, he would require a room, say, 70 feet long by 30 wide and 10 high. This makes it quite clear that in rooms such as we have there must be a change of air.

In studying ventilation from a practical point of view, the chief agents that we have to consider are the winds, and movements produced in the air by variations in its density, usually brought about by variations in its temperature; the property of the diffusion of gases by means of which the air is brought to a uniform composition when the temperature is the same throughout, being one which, practically speaking, does not affect the question much. With artificial methods of ventilation, in which the air is forced in a certain direction by machinery, we have little to do, as few of them are suitable for use in dwelling-houses. The wind, as an agent of ventilation, is powerful, but its disadvantage is that its action is irregular. When all windows and doors can be opened, a current of air which may be imperceptible is quite sufficient to change the air of a house in a very short time, and houses that have windows on both sides are for this reason much more healthy than houses built back to back, which can never have through ventilation. This is the direct action of the wind, which may generally be utilised in large rooms with windows on opposite sides, like schoolrooms, by opening that which is nearest to the direction from which the wind comes, a little way at the top, and also opening at the top the one which is diagonally opposite to it, a little further than the first one. The direct action of the wind has also been utilised for ventilating large houses by Silvester's plan, which consists in having a large cowl, that always faces the wind, at the top of a pipe leading down into cellars in the basement of the house, where the air can be warmed by stoves, and allowed to ascend into the house. By this plan the holds of ships are frequently ventilated. But the aspirating action of the wind is also of the greatest importance. When the wind blows over the top of a chimney, or over a ventilating pipe, it causes a diminution of pressure in the column of air in the chimney or ventilator, and so produces an up-current, upon precisely the same principle that little bottles made for distributing scent about apartments act. For this reason, it is, as was hinted in the last chapter, important that chimneys should be higher than the surrounding buildings, so that any wind that blows may cause or increase an up-draught in them. In this way not only is smoke prevented from descending into the rooms, but the amount of air carried from the rooms up the chimneys is increased, and the ventilation of the house improved. There being, then, in every house, and frequently in every room, a shaft—whether sufficient or not, we will consider bye-and-bye—for the escape of air, it becomes of the first importance for us to consider the means by which air may be admitted into our houses and into our rooms. In summer, and whenever the air is as warm outside the house as inside of it, there is no difficulty about this. We have only to open the windows—wind-doors, remembering the proverb that "Windows were made to open and doors to shut"—on both sides of the house, and the air is generally changed fast enough, but it is in winter, when the air is colder outside the house than inside, that the difficulties arise, and so in speaking of ventilation I shall always assume that the air outside the house is colder, and therefore heavier, and exercises greater pressure than the air inside it. This being the case, it follows that if we open a window, or make an aperture through a wall into the outer air, or through the wall of a room into a passage, or staircase, in which the air is colder than it is in the room, air will come in. In fact, a room under these conditions may be looked upon as if it had water outside of it, and it is quite apparent that, in such a case, if you bored a hole through the wall into the water on the other side, water would come in, and the air of the room would escape by the chimney. This is precisely what happens with the cold air outside. If no special opening is provided through which the cold air can come into a room, it enters by such openings as there are; by the apertures between the sashes of the windows, by the—perhaps fortunately—badly-fitting doors, crevices in the floors, walls, and cupboards, through the walls themselves, as has been shown by Pettenkofer, and sometimes down the chimney. If, then, air will come in through an aperture placed in any position, it becomes necessary to consider where apertures should be placed, and what precautions are necessary with regard to them. Theoretically, the admission of pure air should be at the lowest part of the room, and the extraction of the vitiated air, which is warm, at the upper part of the room; but practically the outer air cannot be admitted at the lower part of the room by mere apertures without certain precautions, as everybody knows who has been accustomed to sit in a room where a draught comes under the door. On the other hand, if an aperture is made into the outer air through a wall at a few feet from the floor, the air enters in a cold straight current for some distance into the room. If the aperture be higher up, it comes in and falls, just as water would do, on to people's heads, somewhere about the middle of the room. So it is quite clear that certain precautions are necessary in the admission of air so as to prevent draughts. Since we have, or ought to have, windows in all rooms, it will be convenient to consider, first, the ways in which they may be utilised for the admission of air. We cannot simply open a sash window at the top or bottom in cold weather without feeling a draught, but there are several ways in which this difficulty may be got over. The simplest is by placing a board of wood underneath the lower sash, as suggested by Dr. Hinckes Bird, whose original model is in the Parkes' Museum. This board is sometimes now made with a hinge in the middle, so that it can be got in and out more easily; or instead of being placed under the lower sash, it may be placed across, from side to side, in front of the lower part of the lower sash, so that this may be opened to a certain height without any air coming in below it. These boards may be covered with green baize, or some other suitable material, so as more perfectly to prevent the entrance of the air at the lower part of the window. In either case, the bars of the sashes at the middle of the window are no longer in contact, and air comes in at the middle of the window, between the two sashes, taking an upward direction, in the form of a fountain, and producing no draught. This shows us the direction in which cold air ought to be admitted into a room—after the fashion of a fountain, in which it can be readily obtained owing to its greater pressure, and not after the fashion of a waterfall.

This simple plan, which I recommend very strongly for adoption, has two disadvantages, one that nervous people always fancy there is a draught if they see anything like a window open, and the other a much more practical one, but one that is common to most forms of ventilation that are inexpensive—that a certain quantity of blacks enter. These conditions are, to a certain extent, got over by the plan suggested by several inventors

—of boring holes through, or cutting pieces out of the lower bar of the upper sash. Such holes are not seen; and the air comes through them in a vertical direction into the room. They can also be fitted with little boxes containing cotton-wool, through which the air will be filtered and deprived of soot, &c. This, of course, very considerably diminishes the amount of air that enters, and the cutting also weakens the framework of the window. I may here mention Currall's window ventilator, which consists of a metal plate fastened along the lower bar of the lower sash, and parallel to it, with an opening below the sash for the admision of air, which is thus deflected into a vertical direction by the metal bar. Here will also be a convenient place to mention the automatic sash fastener patented by Messrs. Tonks and Sons, by means of which the window is securely fastened when opened to the extent of three or four inches, either at the top or bottom, so that the window can be left open without anyone outside being able to open it further. This can also, obviously, be combined with the window block placed underneath the lower sash, so that air can be admitted in the proper direction, and the window still be securely fastened.

Louvred ventilators may also be used in a variety of ways in connection with windows. Where there are venetian blinds, it is only necessary to open the top sash, pull the venetian blind down in front of the opening, and place the louvres so that they give the entering air an upward direction. Glass louvres fixed in a metal framework, may also be used, a pane of the window being taken out and one of these ventilators substituted for it. The louvres can be opened and shut by means of a string, and they are so fixed that it is impossible to break them by doing so. They are generally fixed instead of one of the top panes of the upper sash. It is better to place them lower down in the upper sash; and this is true of all inlets of air. If they are too high up, the air being admitted in an upward direction, impinges against the ceiling, rebounds into the room, and produces a draught. The metal framework of these ventilators requires oiling and attending to, or it will get rusty. In some places fixed louvres of wood, or still better, of strong glass, are employed with advantage, or swinging windows with sashes hung on centres may be used, as, for example, in water-closets; and these, where it is advisable, may be prevented from being closed by means of a small wedge of wood screwed to the framework. The blind so often placed across the lower part of a window may also advantageously be used as a ventilator, or, where no blind is required, a glass one may be used, this being made to swing forward on its lower edge, so as to give the entering air an upward direction when the lower sash is opened, as in a model presented by Messrs. Howard to the Parkes Museum. Where very large quantities of air require to be admitted, one or more sashes of a window may be made to swing forwards in this way, as is now done in the large hall of Willis's Rooms. Near to all windows, in the cold weather, the air of the room is colder than at other parts of the room. This may be obviated, when considered advisable, by the employment of double windows, the layer of air between the two windows preventing, to a very considerable extent, the cooling of the air inside the room. It is not advisable to have double panes of glass in the same sash, as the moisture between them will render them more or less opaque in certain states of the weather. With double windows, air may be admitted by opening the outer one at the bottom and the inner one at the top. Where French casement windows are used, as they sometimes are unadvisedly in this climate, ventilation may be provided by having a louvred opening above the casements of the window, or by making a glass pane, or panes, capable of being swung forward on the lower edge. Lastly, Cooper's ventilator is largely used for windows, and also in the glass panes over street doors. It consists of a circular disc of glass, with five holes in it, placed in front of a pane of glass with five similar holes, and working on an ivory pivot at its centre. It can be moved so that the holes in it are opposite to those in the window pane, when air will, of course, come in; or, so that they are opposite to the places between the holes in the panes, when the air will be prevented from entering. It is obvious that the air is not admitted in an upward direction, but the disadvantage of this is partly counter-balanced by the fact that it is admitted in five small streams, and not in one large one, so that there is less probability of a draught.

The air may also be admitted through apertures made in the walls or doors. The simplest way to do this is to make a hole through the wall, and fasten a piece of board in front of it in a sloping manner, so as to give the air an upward direction. It is better to put "cheeks," as they are called, on the sides, for they serve not only to attach the sloping board to the wall, but to prevent the air from falling out sideways into the room. This ventilator may be hidden by hanging a picture in front of it, and will cause no draught. I may state here that it is better, in a large room, to have two or more small ventilators of any kind whatever than one large one, and that no single inlet opening should be larger than a square foot. Openings of half that size are preferable. It is calculated that there should be 24 square inches of opening per head, so that a square foot would be sufficient for six persons. In such an opening as has been described, wooden or glass louvres may be placed. The same end may be attained by making one of the upper panels of a door to open forwards with hinges to a certain distance; or, even in some instances, by fixing it in this position. An obvious disadvantage, and one which always has to be considered in making openings through walls and doors, is that conversation which goes on in the room can be heard in the passage outside. Sherringham's valve is a modification of this plan, and can be fitted either into an outer wall or into one between the room and the passage or hall. It consists of a metal box to fit into the hole in the wall, with a heavy metal flap, which can swing forwards, and is exactly balanced by a weight at the end of a string passing over a pulley, the weight acting as a handle, by means of which the ventilator can be opened or shut or kept at any desired position. What has been said before applies to these ventilators. They should not be placed too near the ceiling, and this is the mistake that is generally made in fixing them. Stevens's drawer ventilator may also be mentioned here. The name almost describes it. It resembles a drawer, which is pulled out of the wall for a certain distance, and allows air to come into the room vertically in several streams between metal plates placed inside the drawer. Jennings's "Inlet," which is in use in the barracks, consists of an opening through an outer wall, into a chamber in which dust, &c., is deposited, and thence between louvres into the room. Here I may mention that it is sometimes advised to place perforated zinc or wire gauze outside the entrance of the ventilators, so as to prevent dust, &c., coming into the room. This is not advisable, as the apertures get clogged up, and the entrance of air is much impeded. It is better to have an iron grating which will prevent birds entering, and to employ other methods for preventing the entrance of dust, soot, &c. Where this is considered necessary, the plan of passing air through cotton wool, which must be frequently changed, may be adopted. Currall's ventilator for admitting air through the door is sometimes useful. It resembles his window ventilator almost exactly; a long slit is cut through the door, a perforated metal plate placed outside, and a flat plate fixed parallel to the door inside and in front of the slit, thus giving the air as it comes into the room an upward direction. An admirable plan for the admission of air into rooms is by means of vertical tubes—an old system, but one which has been brought into prominence of late years by Mr. Tobin.

A horizontal aperture is made in the wall into the outer air just above the floor, and then a vertical pipe carried against the wall to a height of from five to six feet. The cold air is thus made to ascend like a fountain into the room. It does so in a compact column, which only perceptibly spreads after it has got some height above the mouth of the tube. It then mixes with the warm air at the top of the room, producing no draught at all. In spite of the vertical height through which the air has to pass before it emerges into the room, a considerable amount of soot and dust of various kinds is brought in by it. This may be obviated by placing a little cotton wool in the interior of the tube. This, however, although a very efficient plan, has the serious disadvantage of impeding the current of air. A better one is that patented by the Sanitary Engineering and Ventilating Company; a tray containing water is placed in the horizontal aperture in the wall, the entering air being deflected on to the surface of the water by metal plates. The greater part of the dust is thus arrested by the water, which can be changed as often as necessary. In warm weather ice may be placed in the trays. Another plan is to place in a vertical tube a long muslin bag with the pointed end upwards, and kept in shape by wire rings. This provides a large filtering area, and offers very little resistance to the passage of air. The bag may be taken out and cleansed from time to time.

Several contrivances have been devised for the admission of air close to the floor, just behind a perforated skirting board. Among these are Ellison's conical ventilator, mentioned in the last chapter, and Stevens's skirting board ventilator, in which metal cups are placed in front of the inlet openings, and so distribute the air that no draught is felt. I think however, that it is only advisable to admit warmed air at a low level into rooms, but there is no reason why such openings should not be made high up in the rooms—behind cornices, for example. Prichett's paving, made of agricultural pipes, may also be used for making walls and partitions, and is obviously applicable for ventilating purposes, whether used as inlet or outlet.

We now come to speak of exit shafts and valves. The first and most important of these is the chimney, about which I have already spoken. I need only add here that it is advisable to do without the use of cowls upon chimneys wherever it is possible. If the chimney can be made high enough it will not require a cowl, and if it cannot, a simple conical cap is generally sufficient to prevent down draughts. There is no doubt, however, that Boyle's fixed chimney cowl for preventing down draught not only does so, but produces an up draught in the chimney when the wind blows down upon it, as can be readily shown by an experiment with a model. A small piece of wool is made to ascend in a glass tube by blowing vertically down upon the fixed model cowl placed upon the top of it. Of revolving cowls for chimneys, the common lobster-backed cowl is probably the best. Of the many cowls which have been invented with the object of increasing the up draught in exit shafts of various kinds, some are fixed, as Boyle's, Buchan's, Stevens's, and Lloyd's, and some revolving, as Scott, Adie, and Co's., Howarth's, Stidder's, Banner's, and the one invented by Mr. Boyle, but discarded by him some years ago. Whether any of these cowls increase the up current in exit shafts is a matter which is still under investigation, but it is easy to show that the common rough experiment, by means of which they are supposed to do so, is entirely fallacious. Cotton wool is drawn up a tube at least as easily by blowing across it in a slanting direction as by blowing through a cowl placed on the top of it. The fixed cowls have the advantage that they cannot get out of order. The revolving cowls have the disadvantage which is common to all apparatus with moving parts, that they are certain to get out of order some day or other. Whether they increase up draughts or not, there is no doubt that most of them prevent down draughts, and, like any other cover, prevent the entrance of rain.

Openings are sometimes made high up in the room into the chimney flue and protected by valves, the best known of which is Arnott's valve, which consists of a light metal flap, swinging inside a metal framework in such a way that it can open towards the chimney flue, but not towards the room. Any pressure of air from the room towards the flue will, therefore, open it and allow the air to escape from the room into the flue. Pressure of air the other way will shut it. The disadvantages of this ventilator are that it makes an irregular noise, although this has been, to a considerable extent, obviated by the india-rubber padding with which it is now fitted. It also occasionally admits a little soot, and, of course, air at the same time, from the flue into the room. Boyle's chimney ventilator, made by Messrs. Comyn, Ching, and Co., is a modification of this. Instead of the light metal flaps, there are a number of small talc flaps. These make little or no noise, but they are liable to be opened by a current of air in the chimney. It is obviously, it seems to me, at variance with sound sanitary principles to make openings from the interior of rooms into the chimney flues, and then to trust to valves for preventing the air of the flue from coming in. A far better plan is to have shafts placed by the side of the flues, and this, of course, is better done when the houses are built. The easiest and most satisfactory way of doing it is by means of air and smoke flues combined, in which the air flues are moulded in the same piece of fireclay as the smoke flue itself. These air flues can be connected with the upper parts of the rooms, and up draughts will be inevitably caused, as the air in them will be considerably heated on account of its immediate contact with the outer side of the flue. Such shafts often become inlets when the flues are cold, and so it is advisable to use them especially with flues that are always hot—as, for instance, that of the kitchen chimney—and it is desirable, wherever it can be done, to connect the kitchen with a different air-shaft from the other rooms, or it is possible that air from the kitchen may get into some of the other rooms of the house.

Of exit ventilators not connected with the chimney flues, I may mention Mackinnell's, which also provides an inlet for air as well, and which is very useful in little rooms, closets, &c., having no rooms over them. It consists of two tubes, one inside the other, passing through the ceiling into the outer air. The inner one is longer than the outer one, and projects above it outside, and below it an inch or so into the room. At its lower end, a circular rim is attached horizontally, parallel to the ceiling. The outer air enters between these two tubes, and is deflected by the rim just mentioned along the ceiling, so that it does not fall straight into the room. The vitiated hot air passes out by the inner tube, the action of which is, of course, considerably increased if a gas burner or other light be placed beneath it. It is upon this principle that the lamps for lighting railway carriages are made, the reflector answering the purpose of the rim round the end of the inner tube, and the air to supply the lamp coming in between the reflector and the glass shade, while the products of combustion escape through the pipe leading from the middle of the reflector, and immediately over the flame. Of course Mackinnell's ventilator requires a cover to keep out the rain, and it is necessary, in fact, to have a double cover, so that the heated air which escapes by the inner tube shall not be carried back into the room by the entering air. Tossell's ventilator is a variety of this, with a cover by means of which the action of the wind is able to be taken advantage of. The same inventor has also contrived one which can be used between the ceiling of one room and the floor of the room above, provided that this space can be well ventilated.

This brings us naturally to say a little about lighting. Candles, lamps, and gas, help to render the air impure.

It is calculated that two sperm candles, or one good oil lamp, render the air about as impure as one man does, whereas one gas burner will consume as much oxygen and give out as much carbonic acid as five or six men, or even more. This is why it is commonly considered that gas is more injurious than lamps or candles, and so it is when the quantities of light are not compared, but with the same quantity of light, gas renders the air of a room less impure than either lamps or candles. If, in the dining-room, instead of using five or six gas burners, as we too often do without any provision for the escape of the products of combustion, we used 40 or 50 sperm candles instead of 6 or 8, we should have a fairer comparison between gas and candles.

I have no time to enter into a discussion of the relative merits of various kinds of candles and lamps, but with regard to gas I would say that, considering the fact I have just stated, it is always advisable to provide a means of escape for the products of combustion immediately over the gas burners. By this, not only may these products be carried away, but, with a little contrivance, heated air may be drawn out of the room at the same time, and so an efficient exit shaft provided, in addition to the one found already in the chimney. Very simple contrivances will answer this purpose. A pipe, with a funnel-shaped end, starting from over the gas burner, and carried straight out into the open air, is all that is required in some instances, as in badly placed closets (an air inlet being provided). For large rooms, the sunlight ventilators are found to answer admirably. They should be provided with a glass shade, placed below them to intercept the glare, and to cut off a large portion of the heat. An elegant contrivance for dwelling-rooms is Benham's ventilating globe light. In this, the products of combustion of the gas pass along a pipe placed between the ceiling and the the floor of the room above, into one of the flues. This pipe is surrounded by another opening through the ceiling of the room at one end, and into the flue at the other, and guarded at its entrance to the flue by a valve which can be easily shut when the gas is not burning. This double tube, as it passes under the floor of the room above, is covered with a fire-proof material, so that the floor is not affected by it. The joists, where they are notched, have iron bearers put across to support the floor boards above. Air is admitted by another pipe passing through the wall of the house into the external air, and ending also in the ceiling of the room by openings around those of the exit shaft. Thus warm air is introduced into the room at the same time that vitiated air from the upper part of the room, and also the products of combustion of the gas, are carried out of it into the chimney flue.

I may say a few words about some grates and stoves that have been devised with the view of combining ventilation and heating. The first of these is Captain Douglas Galton's grate, in which there is an air chamber placed around the flue, and communicating on one side with the external air, and on the other with the atmosphere of the room by various apertures. The outer air which passes into this chamber is warmed by contact with the heated flue, and issues into the room, thus supplying the room with warmed air, and utilising a considerable quantity of the heat that would otherwise be lost. There are several other grates, such as the Manchester school grate, made upon this principle, with variations in the arrangement of the inlet apertures, which are placed vertically like Tobin's tubes, &c. It is important in all these contrivances, where the outer air passes through a chamber in which the back of the grate and the flue is placed, that the back of the grate and the commencement of the flue in that chamber should be cast in one piece of metal, so as to have no joint. If there are joints they will become after a time defective, and air from the flue is liable to escape into the chamber round it and be brought back into the room by the entering air. The back of the grate should also be lined with fire-clay. Some slow combustion stoves, as George's "calorigen," have air pipes passing through them, and have the external air warmed on its way through the stove into the room. Iron slow combustion stoves dry the air too much, and unless they are lined with fire-clay, are apt to become too hot, and to cause an unpleasant smell in the room by the charring of the organic matter in the air. They are much more suitable for warming large buildings, where economy of fuel is an important object, than they are for use in sitting-rooms or offices. It is usual to place a vessel of water on the top of these with the view of obviating, as far as possible, the dryness of the air they produce. It must be borne in mind that closed slow combustion stoves do not act as ventilators, as the air to supply the fuel—usually coke—is brought by a pipe from the outside, and this is another reason why they are not so advantageous as an open fire or a quick combustion stove in dwelling-rooms. In the Thermhydric grate of Mr. Saxon Snell, a small boiler is placed behind the grate, and communicates with a series of iron pipes alongside of it. These are filled with water, which is, of course, kept warm, and air is admitted to the room between these hot water pipes. Thus, it is neither dried nor heated too much. The products of combustion are carried away by a flue, which may be placed under the floor; so that the grates, if required, may stand in the middle or in any other part of the room.

Gas stoves are gradually becoming largely used instead of coal, and, when proper provision is made for the escape of the products of combustion, they are certainly very convenient and cleanly contrivances. I have no doubt that this will, in the end, be found to be the proper use for gas, and that we shall cease entirely, or almost entirely, to use coal in our houses. By using coal in the way that we do, we lose all the valuable bye-products—the ammonia, the tar, the carbolic acid, aniline dyes, &c., which are derived from the refuse of gas-works, and which are worse than useless to us in our fires. Gas may be burned either mixed with air or not. In the first instance, a gas stove or grate filled with pumice-stone or asbestos does not much resemble an ordinary fire, but if the gas be burned unmixed with air it is almost impossible to tell the difference. Generally speaking, it is found necessary, when there are several gas stoves in a house, to have a special supply of gas with larger pipes for them. What the gas companies should do is to lend gas stoves of various kinds, especially cooking stoves, to their customers for a small annual payment, as is done very successfully in some continental cities. It is important that gas cooking stoves should not give an unpleasant smell of unburnt gas as some do. This is not only a waste but a nuisance, as coal gas always contains carbonic oxide (an extremely poisonous substance), and should, therefore, not be allowed to escape into the air, even in the smallest quantity.

I have now to mention an artificial system of ventilation which has been lately introduced by Messrs. Verity Bros. It consists essentially of a fly-wheel fitted with fans or vanes. The wheel is made to revolve by a jet of water directed against it, and supplied from a cistern overhead, the water passing off by a pipe into a cistern below. The apparatus can be fixed either in an inlet opening, and so made to propel air into the apartment through an aperture in the wall placed higher than people's heads, and in a slanting direction, so that the entering air is shot upwards towards the centre of the room; or it can be used as an extractor, by placing it in an exit shaft, and causing it to draw the vitiated air out. The supply of water can be regulated by taps to the greatest nicety, so that the wheel can be made to revolve at whatever speed is desirable. The entrance pipes are sometimes fitted with a vertical tube containing a box, in which ice can be placed, or a holder for perfume, or any deodorant. For smoking rooms it is found advisable to use the apparatus as an extractor only, and to allow the air to come in by means of Tobin's tubes, and this will probably be found to be the best plan generally.

Dwelling-houses are seldom warmed and ventilated by means of hot-water apparatus, and so I do not think it necessary to enter into a description of the plans by which this may be effected. I need only mention Mr. Prichett's "minature hot water apparatus," if I may so call it, by means of which a single room may be warmed and ventilated. The water starts from a small boiler, of the size of an ordinary kettle, which may be placed on a fire anywhere, or heated by a spirit lamp, and passes through a narrow space between double cylinders, the inner cylinders being used for the admission of fresh air, which is warmed in passing through them, or for the extraction of foul air. The water is made to pass through the extraction cylinders first, while it is hottest, and then through the others and back to the boiler. The cylinders are placed vertically, so that the air is admitted into the room in the proper direction. Other systems of artificial ventilation are suited for large public buildings, but are not adapted for use in dwelling-houses.

CHAPTER III.

Water Supply.

For the purpose of these lectures we must assume that it is necessary to have a supply of water that is fit to drink sufficient for all uses. The obvious characters of a good drinking water are that it is clear, transparent and colourless, without taste (that is to say, neither salt nor sweet) and without smell; that it has no suspended particles in it, and produces no deposit on standing, and that it is aërated; but a water may possess all these characteristics and yet be unfit to drink, by reason of dissolved matters which cannot be detected except by chemical analysis, but the existence of which may often be suspected through a knowledge of the history of the water. Waters are commonly divided into hard waters and soft waters. Hard waters are those which contain a considerable quantity of mineral salts, especially salts of lime, in solution; soft waters, those which contain much smaller quantities of these substances. Very hard waters are unfit for domestic purposes. A deposit of mineral matters takes place in the supply pipes, &c., and they get blocked up. Such very hard waters, too, are not desirable either for drinking or for domestic purposes generally. Moderately hard waters appear to be as wholesome as soft waters for drinking purposes. The Registrar-General has shown that the death-rate in towns supplied with moderately hard water, does not differ sensibly from that of a series of towns supplied with soft water, but in other respects similar in their sanitary arrangements. Nevertheless animals in their natural state prefer soft water to hard, and those who have the care of horses always give them soft water to drink if possible. An undoubted disadvantage that attends the use of hard water for domestic purposes consists in the enormous waste of soap that it entails. In order to wash with soap it is necessary to produce lather. Now, the mineral salts in hard water decompose the soap, and form insoluble compounds, so that solution of the soap in water which will form a lather, does not take place until the lime, &c. in the water has been deposited as insoluble lime-soap, &c. Thus the more salts of lime and other mineral matters are present in the water, the more soap is wasted before the formation of a lather. This can be easily illustrated by a simple experiment. If we take a sample of distilled water, which contains no mineral matters in solution, and add a small quantity of an alcoholic solution of soap to it —when we shake the bottle in which it is, a lather is immediately produced and remains for some time; but when we take the same quantity of a sample of hard water, and add the soap solution to it, we find that it requires say, ten or twenty times as much of the solution to form a lather. Soft water then, on the whole, must be preferred to hard for domestic purposes, and when the water is very hard it ought to be softened before being distributed. This may be done by Clark's process, which consists in adding milk of lime to the water as long as a precipitate is formed. The rationale of this is that most of the hard waters contain considerable quantities of carbonate of lime, which are held in solution in the water by means of free carbonic acid. The lime added as milk of lime combines with the free carbonic acid, forming more carbonate of lime, which, together with the carbonate previously in solution, is deposited, being almost entirely insoluble in water. As it is deposited, it carries down with it any suspended matters that may be in the water, and so leaves the water clearer and purer. A practical difficulty in the carrying out of this process, arising from the length of time required for the precipitate to subside, has been overcome by a process of filtration devised by Mr. Porter, and known as the "Porter-Clark process." Water after being distributed may be softened to a considerable extent on a small scale by boiling, when the carbonic acid gas is given off, and the carbonate of lime deposited. It is this which causes the incrustation of boilers. The boiling also helps to purify the water in other ways, and it is a very good plan to use boiled water, either when the water is very hard, or when there is any suspicion of impurity, both for drinking and for domestic purposes generally. It may be aërated by allowing it to fall from a height from one vessel into another. The average quantity of water required in a community is generally put down at from 30 to 35 gallons per head daily. Of these, from 20 to 25 are required for household purposes (including waste) where baths and water-closets have to be supplied, and ten or more are necessary for washing the streets, for flushing the sewers, and for trade purposes.

The important sources of water are:—(1.) Rain collected directly. This is of course very soft water, and in country places very pure. In towns it is rendered impure by the substances that it washes out of the air, and must be filtered before it is used, but it is everywhere an important and valuable source of soft water which is far too much neglected. It ought to be collected and used for domestic purposes, and wherever there is any suspicion as to the quality of the water supplied from other sources, rain-water should (especially in the country) be used for drinking. It may be filtered through sand, gravel, or charcoal by means of very simple contrivances.

(2.) Water is often obtained from shallow wells, dug in the soil down to a little below the level of the subsoil water. These, of course, drain the soil around for a greater or less distance, and the water in them frequently becomes contaminated by foul matters from leaky sewers, cesspools, &c., especially in pervious soils. Persons should therefore always be suspicious of the quality of water derived from shallow wells, for frequently, even when bright and sparkling, it is highly contaminated.

(3.) Springs and small streams are often used to provide supplies of water, and very pure water is obtained in this way, although it is sometimes rather hard. It is either conveyed directly to the town by means of aqueducts or pipes, after the Roman plan, or collected from a gathering ground into large impounding reservoirs, and thence taken in pipes to the place to be supplied. Lakes are sometimes utilised.

(4.) The water of large rivers is now frequently used as a source of supply. It is received in settling basins or reservoirs, where a deposit takes place, then filtered through beds of sand and gravel, and afterwards distributed. Most of the river water is contaminated in various ways during its passage through towns; and without entering further into the subject here, I would merely say that it is better to obtain water that has not been contaminated, than to take water which we know has been contaminated, and then try to purify it.

(5.) Water is sometimes obtained from pervious water-bearing strata, at a considerable depth below the surface of the ground, by boring into them through the impervious strata which lie over them, and through which the water cannot penetrate. Wells with such borings from the bottom of them are known as artesian wells, from having been first generally used in the French province of Artois. The water contained in such water-bearing strata is supplied by the rain which falls on the outcrop of these strata, often at a considerable distance, and frequently, as in London and Paris, on the hills around. This water percolates through the pervious rocks, and so gets beneath the impervious strata which lie over them after they have disappeared beneath the surface, and, being retained there under pressure, rises through borings made into the rock in which it is, through the impervious strata lying over it. This water, then, is generally, as may be expected, very pure, although it is frequently, especially if derived from the chalk, as that supplied by the Kent Company to London, very hard. Occasionally, as in some wells bored into the New Red Sandstone, it contains too much common salt to be fit for domestic purposes, which will not be wondered at when we consider that the largest deposits of salt we have, from which enormous quantities are obtained, are in the New Red Sandstone formation.

However the water is obtained, it is distributed to the houses in one of two ways, either by intermittent or by constant service. With the system of intermittent service, the water is turned on into the houses once or twice in the 24 hours for a short period each time. It is, therefore, necessary to have cisterns, butts, tanks, or receptacles of some kind to keep the water in during the intervals. In these, deposit occurs of the suspended matters contained in the water, and dust accumulates, especially if they are not covered, or if the covers are broken, and so the water is rendered impure. They also usually have a waste or over-flow pipe, which is frequently connected with the sewers, or with some part of the water-closet apparatus, and by means of which foul air finds its way into the cistern and contaminates the water. During the intervals, too, when the mains are not charged with water, foul water and foul air find their way from the soil around through leaky joints, and contaminate the water when it is next turned on, so that it frequently happens that the first water that comes into the cistern when it is turned on is quite unfit to drink. There is an enormous amount of loss with this system, which might, however, in great part be prevented. The last disadvantage of the intermittent supply lies in the fact that some delay is frequently experienced in obtaining water for extinguishing fires.

With the system of constant service, on the other hand, the pipes are always full, and so it is not necessary to have cisterns, or receptacles of any kind for the storage of drinking water, although this is frequently done. Receptacles are, however, necessary for the supply of water to closets. The pipes being always full of water under pressure, are far more likely to leak out into the soil than to be contaminated with foul matters from the soil. Still, it is not advisable on any account that waterpipes should be carried near to sewers or other sources of contamination. The water is fresher, and purer, and cooler in summer when supplied on the constant service system. The pipes are full in case of fire, and the inspection of pipes, taps, and other fittings is, as a matter of fact, carried on very much better, and less waste of water takes place under this system (although the pipes are always charged) than under the other system. It is obvious that, unless there were very strict supervision, a great waste of water would necessarily accompany the use of the constant system. For this reason also the water companies that have adopted that system will not allow waste pipes from cisterns to be connected with the sewers, or closet apparatus, but insist on their discharging freely in the open air; and usually in some place where any waste water running out of them would produce annoyance, so that it would be speedily noticed, and the cause of the waste remedied. It is very important, however, where this system is adopted, that there should be double reservoirs or tanks in order that one may be used while the other is being cleaned out, for if, as has been the case at some places, and notably at Croydon, the water be supplied by the intermittent system of service for a few days, defects which have produced no inconvenient results while the constant system of supply was practised (such as the connection of water-closet hoppers directly with the main water-pipes, the existence of leaky joints in the mains, through which foul matters may enter from the soil, &c.), may produce the gravest results by spreading enteric fever throughout the community; and here I may mention that it is, of course, extremely improper and very dangerous to connect a cistern which is used to supply drinking-water, or a water-supply pipe, directly with the hopper of a water-closet. The system of constant service is coming gradually into more general use, and it is very probable that water-meters will be much more generally used than they are at present. A simple apparatus of this kind is Ahrbecker's water-meter, in which the water is made to pass through oblique apertures in a fixed plate into oblique or spiral passages in a cylinder which is capable of rotating, and the axle of which turns the index of a dial. The pipes, by means of which the supply of water is conveyed into the houses from the mains, are usually made of lead; this material being preferred on account of its durability, and the facility with which it can be bent in various directions. A disadvantage of it is, that certain waters attack and dissolve lead, and are thereby rendered more or less poisonous. Those however, are chiefly pure and soft waters. Waters containing mineral salts in solution, such as those generally supplied for drinking purposes, scarcely attack lead at all; and moreover, with waters which do attack lead, the surface of the metal becomes covered with an insoluble coating of oxide and carbonate, which protects it from further attack. Pipes made of lead lined with a thin layer of tin are sometimes used, but when the tin becomes damaged in any way, a galvanic action is set up, and the lead is dissolved quicker than ever. Varnishes of various kinds have been proposed for coating the interior of water-mains and pipes. Most of them are very objectionable—one of them positively containing arsenic. Wrought iron pipes with screw joints are sometimes used for water pipes. They are certainly cheaper than lead, and it is said that they will last longer. Bends are made of almost every possible shape just as in gas pipes. In some rare instances lead pipes are attacked from the outside by water containing carbonic acid in the soil, as shown in a sample of a lead pipe which had been laid in chalk, and which was contributed to the Parkes Museum by Mr. Bostel, of Brighton.

The receptacles used for storing drinking water are made of various materials. Cisterns of lead have long been frequently used on account of their durability. They are open to the same objections as lead pipes, although from the fact that no mischief has been found to result from the use of lead pipes and cisterns at Glasgow, since it has been supplied with Loch Katrine water, which is exceedingly soft, it appears probable that the ill-effects from the use of lead in this way have been exaggerated. Galvanised iron cisterns are fast taking the place of lead ones. They are very durable, and of course far cheaper than lead. Stone or even brickwork lined with cement are sometimes used at or below the ground level for the storage of water, and are open to no objections so far as the material is concerned. Stoneware cisterns are now made and are admirably suited for cottages, for use in basement floors, &c. Slate cisterns are not unfrequently used for upper stories, as well as ground floors. Of course slate in itself is an excellent material for such a purpose but slate cisterns, unfortunately, are very apt to leak after a time, and the joints are then filled in with red lead from the inside of the cistern—a practice which is, of course, very objectionable. The use of wooden receptacles, such as tubs, butts, &c., ought to be discouraged, if only because they are difficult to be kept cleansed. A self-cleansing tank is sold by the Sanitary Engineering and Ventilating Company. The bottom, instead of being flat is made to slope from all sides towards the centre, where the waste-pipe is fixed. On lifting up, by means of a lever, that part of the waste pipe which stands up in the cistern, and which is fitted accurately into the commencement of the pipe at the bottom of the cistern, so as to make a water-tight joint, the water runs out of the cistern, and on account of the sloping bottom washes all the sediment away with it. The water is generally supplied to the cistern from the pipes through a tap known as the "ball-valve." To it is attached, by means of a metal bar, a hollow copper sphere or ball, which floats on the water as it rises in the cistern, and when it has risen to a certain height turns off the tap. It is because these taps are liable to get out of order, that a waste or overflow pipe is necessary. This waste or overflow pipe should, in all cases, without any exception, discharge freely, as over an area, &c., so that you can see the water coming out at it. All receptacles of water should be well covered, in order that dust may be kept out of them. Nevertheless, ventilation space between the water and the cover, by means of holes provided with a grating, at the sides, is advisable.

Of course, for drinking water, we ought to choose a source of supply that is unpolluted. As Mr. Simon has said, "It ought to be an absolute condition for a public water supply that it should be uncontaminable by drainage." We ought not, then, to take confessedly impure waters and try to purify them, so as to make them fit to drink. On the other hand, it is obviously unnecessary to use very pure water, except where there is a superabundance of it, for washing the streets, flushing the sewers, and supplying the water-closets, and so it may be advisable in some places to have a double supply of water, one of pure water for drinking and cooking, derived, for instance, from artesian wells, and the other of an inferior character for other uses. This has been lately proposed for London, and whatever may be said against it on the score of expense, I think most people will agree that it will be very desirable to have water to drink which has not been first polluted with sewage and then filtered. The advantage of this plan, too, was perfectly well recognised by the ancient

Romans. Frontinus tells us that it pleased the Emperor (as he puts it) to order that the water supplied by certain aqueducts should be furnished to the people for domestic purposes, while that supplied by some others, from its being occasionally turbid and of inferior quality, was to be used for "viler purposes."

As, however, we do not, as a matter of fact in the majority of instances, imitate the ancient Romans, either in this particular or in bringing pure water from a distance to supply the towns, but use the nearest water that we can get, whether good, indifferent, or bad, it is of course necessary for us to do all that we can to purify it before use. This is done on a large scale by filtration through layers of sand and gravel, after the coarser suspended matters have been allowed to deposit themselves in a settling tank. I shall not describe this method of filtration in detail here, as it is a little beside the scope of these lectures, but, as the principle on which it acts is the same as that upon which the success of most forms of domestic filter depend, I may say a few words about it once for all. The experiments made by Dr. Frankland for the Rivers Pollution Commissioners showed that when foul water was passed through layers of porous soil, or sand and gravel, the amount of organic matter in it was reduced, if two conditions were fulfilled; these are, that the filtration be downwards and intermittent. It was found that if the filtration were upwards or continuous, no such purification occurred after a time. The explanation of these facts is simple. The filtering material acts in two ways. It separates, mechanically, suspended matters in the water that are too large to pass through the pores of the filtering material, and it also acts chemically by means of the oxygen of the air in its pores, for as the water flows downwards through the filtering material, it percolates by means of a number of very small streams, and so is brought into the most immediate contact with the oxygen of the air in the filtering material. Thus, the organic matter and ammonia dissolved in the water are oxydised with the production of nitrates and carbonates, and it is certain that by this means a considerable quantity of organic matter is reduced to a harmless condition. Domestic filters, clearly, ought not to be required. The water ought to be delivered sufficiently pure to drink.

And here I would remark that the average quality of a drinking water supplied to a place is not the matter of most importance, and, indeed is rather a fallacious guide. What we want to know is the quality of the worst sample that the public are likely to be supplied with at any time. But it is not only because the water supplied varies in purity in most instances, sometimes considerably, that domestic filters are useful, but because, as I have before remarked, especially where the intermittent system of supply is in vogue, the water, even if delivered pure, is rendered impure in the houses themselves by being stored in filthy receptacles. The majority of the filters in domestic use rely upon the principle of downward filtration. In a few, the water is passed upwards through a filtering material. The chief materials used are animal charcoal—vegetable charcoal is not a good material for filtering purposes—

silicated carbon, carbide of iron, spongy iron and sand. When animal charcoal is used, it must be specially prepared and well-burned. If any of the animal matter be left in it, it becomes, as has been shown by the Rivers Pollution Commissioners, a breeding place for myriads of small worms which pass into the water. With the other materials mentioned, there is, of course, no risk of this, as they are made of burnt shale, or taken from the interior of blast furnaces. Some filters are placed inside the cisterns, so that all the water that is drawn off has to pass through them. Others are placed on the main water pipes themselves, or in the taps. One of the former kind, known as "the self-cleansing filter," in which the suspended particles in the water are prevented from getting at the filtering material by a ring of compact silicated carbon, and the water itself is made to wash the outside of the block of filtering material through which it has to pass. My experience goes to prove that filters that are always under water, cease to purify the water after a time, unless means are taken for aërating them, and in many instances I have known water to be rendered more impure by its passage through a filter which has been used in this way for a considerable time. Of forms of domestic filter, the glass decanter with a solid carbon or silicated carbon block has the great advantage that every part of it can be seen, so that it can be kept scrupulously clean. These filters go on working perfectly well for an almost unlimited time, scarcely anything being necessary beyond cleansing the surface of the block once now and then with a hard brush. It is a very good plan to have a kind of double filtration. Sometimes the water is made to pass through a piece of sponge before falling on to the filtering material with the view of arresting the coarser suspended matters. It is far preferable, however, to use the carbon block for this purpose. In Prof. Bischoff's spongy iron filter the filtering material is always under water, and the action which goes on in it is certainly quite different to that which I have explained and is as yet little understood. The Rivers Pollution Commissioners have expressed the highest opinions of this substance as a filtering material. On account of the fact that the water dissolves a little of the iron on its passage through the spongy iron, it is made to pass through a layer of prepared sand afterwards, with the view of removing this, and then, in order to aërate it, it is delivered through a very small hole in a fine stream into the pure water receiver. It will thus be seen that it is rather more complicated than some of the other forms of domestic filter. The slight trace of iron that remains in the water can hardly be considered a disadvantage, at any rate in large towns.

Lastly, I must notice the filter made by the General Sanitary Engineering and Ventilating Company. In this, by an ingenious contrivance, the air passes to and from the filtered water chamber through the filtering material itself, and not by means of a small channel in the china or earthenware vessel holding the filtering material, as is the case in other filters. The water first passes through a silicated carbon block, and then falls in the form of a shower on to the surface of a layer of some loose silicated carbon supported upon a perforated plate which is not flat, but has elevations here and there on its surface. The result is, that not only when the water is drawn off by the tap does air pass through the filtering material into the filtered water-chamber, but also as the water flows through into this lower chamber it forces the air out through the filtering material itself, which it is enabled to do by means of irregularities on the surface of the plate upon which the filtering material rests. If this plate were quite flat as it was heretofore made, and if there were no air-pipe from the lower chamber, a balance would be established and both water and air would cease to pass through the filtering material.

When rain-water is used for drinking, and even for other domestic purposes, it is advisable to filter it, and a very good filter for this purpose is one devised by Professor Rolleston, of Oxford. The tank to receive the rain water has two compartments, divided from one another by a vertical partition, and each having a horizontal layer of filtering material, as charcoal, placed on a perforated support half-way down the tank. The rain-water pipe from the roof is brought down through this filter-bed, nearly to the bottom of one of the compartments. The rain-water then has to pass upwards through the filtering material in this compartment over the partition into the second compartment, and downwards through the filtering material there, into the lower part of that compartment, where there is a tap from which it may be drawn off. An overflow pipe is, of course, provided, so that the water cannot rise above a certain level.

In conclusion, I need only say that the number of instances in which epidemics of typhoid fever, cholera, and some other diseases, have been traced to the use of impure water, or of milk contaminated with foul water, must make it evident to everyone that it is of the greatest possible importance that we should have uncontaminated sources of water supply.

CHAPTER IV.

Removal of Refuse Matters.

Dust. Kitchen Refuse, Earth-closets, &c. Conservancy and Water-carriage Systems Compared.

A very important matter in the sanitary administration of large towns, and an important matter for the consideration of every householder is the regular and frequent removal of the house refuse known as "dust." This consists chiefly of ashes and cinders; but, unfortunately, the dust-bin or ash-pit is only too convenient a receptacle for all kinds of refuse matters, including kitchen *débris*, and so, in a large number of instances, these receptacles, especially in hot weather, become excessively foul, and an abominable nuisance. If the dust were removed daily, as it should be wherever this is practicable, the mixture of organic matter with it would not be of great importance, but where this cannot be done, it is very neccessary to insist that the dust-bin shall be used for nothing but ashes, and that all organic kitchen refuse, such as cabbage leaves and stalks, shall be burnt. This can be done without any nuisance by piling them on the remains of the kitchen fire the last thing at night; thus they are gradually dried during the night, and help to light the fire in the morning. When dust is valuable to those who contract to remove it (for this work is generally let out to contractors by the parish authorities, although in several instances it is now being done with great advantage and saving to the ratepayers by the parish workmen themselves), there is no difficulty in getting it removed. The contractors are only too glad to get it, and even prosecute people who keep any of it back for their own uses. The cinders and ashes from dust-bins are largely used in brickmaking, and so when the building trade is slack dust becomes worthless. The contractors, instead of paying for it, require to be paid considerable sums to take it away, and the less they take away, and less frequently they call for it, the more advantage do they get out of their bargains. This has been the case for some years, and in one parish alone, that of Islington, where I was formerly Medical Officer of Health, the difference that it made to the sanitary authority in one year as compared with another only six years before, was no less than £6,257; whereas in the former year the sanitary authority received £2,200 from the contractors in the latter they had to pay £4,057. No doubt the best plan to get rid of such refuse matters would be to put them outside the door early in the morning in a box or bucket, to be called for every morning by the contractor's men, and this is already done in some places. Otherwise it is necessary for every householder to take care that his dust-bin does not become a nuisance to himself or his neighbours, from too large an accumlation being allowed to remain in it, or from improper matters being thrown into it. Dust receptacles ought not be kept inside houses, as they very frequently are. Neither ought they to be built against the wall of the house, unless cased with an impervious layer of cement, to prevent emanations from them percolating through the walls into the interior of the house. They ought always to be covered with a sloping roof, so that the rain may run off; if rain water is allowed to get into them, they are much more likely to become a nuisance. Rain-water pipes ought not to be carried through dust-bins, or foul air from the latter will get into the pipe through a leaky joint, or a damaged place, and ascend it, causing a nuisance in one of the upper rooms, or elsewhere. I have known a serious nuisance caused in this way.

Removal of Excretal Matters by Conservancy Systems.

Under these systems the excretal matters are either collected without any admixture, in receptacles known as cesspools, or they are mixed with ashes, and other house refuse, forming what is called a "midden heap," and of these two old plans all the dry closets, pail, and tub systems, &c., may be said to be modifications. Cesspools were formerly largely used, especially for houses built on porous soils. A pit was dug into which the excretal matters were discharged and allowed to percolate away into the soil—frequently into neighbouring wells. Often there was not only no pretence at making this pit impervious, but every facility was given to allow of the percolation of the foul water, &c., into the soil around. Thus the walls (when there were any) were made merely of rough blocks of stone placed one upon another. In some instances these pits were not opened for many years together. Such cesspools were constructed long before water-closets came into use, and were often retained after the introduction of these. In many instances, they are placed underneath houses, and under the basements of large houses there are sometimes several of them. They form a serious nuisance, lasting for many years, as foul air from them finds its way into the house, even when there are no waste pipes directly connected with them, as there generally are, and thus they are very dangerous to health, even supposing they are so placed as not to contaminate the water supply. In some towns it was, positively, formerly a practice to dig them down until a spring, or water of some kind, was reached, in order that they might not require to be emptied. In all old houses, it is imperative to search diligently for unused cesspools and to trace the course of every pipe from every part of the house. In many instances, openings from the basement floor lead into disused cesspools, even in houses that have been drained, and the cesspools presumably abolished. A basement drain is not unfrequently allowed to discharge into an old cesspool, after a properly constructed sewer has been made to receive the refuse matters from the water-closets. This is a source of great danger to the inmates of the house.

In some instances, however, cesspools are made of brickwork set in cement and lined internally with a layer of cement, so as to be impervious to water. They then require to be emptied periodically, a process which often causes a considerable nuisance, and they require, moreover, to be at a considerable distance from the house, and to be disconnected from the house drains and sewers in a manner that will be described in the next lecture. Not unfrequenty, however, they are placed directly underneath the house or under the court-yard, as is commonly the practice in Paris and and many other continental cities and towns. Pipes are laid straight into them from the various storeys of the house, and sometimes these are the only ventilating pipes through which foul air can escape. Occasionally they are made to overflow into sewers or drains, and sometimes a kind of strainer is placed inside them, so that the solid refuse may be collected, and the liquids allowed to escape into a sewer or drain. They used formerly to be emptied by hand and bucket, thereby causing an abominable nuisance, and the workmen employed for this purpose were frequently suffocated by the foul air, and suffered from inflammation of the eyes caused by the ammoniacal vapours. Of late years, they have been emptied by hose into air-tight carts, from which the air has been previously exhausted by a powerful pump. This process, of course, causes less nuisance, and is not dangerous to the men employed, but, even with these improvements, the system is a very disagreeable one.

In some towns, large midden heaps are still in vogue. The mixture of ashes and other house refuse with the excretal matters produces a dried mass, which, if not exposed to the rain is considered to cause less nuisance than cesspools; but if dust-bins are bad and are nuisances, as they most certainly are in a very large number of instances, midden heaps must be very much worse. Refuse matters become nuisances and injurious to health when they are allowed to remain in the vicinity of habitations. In all towns where refuse matters are not removed immediately there is a high death-rate, and especially a high children's death-rate, and in all towns (as Dr. Buchanan has shown in the ninth report of the Medical Officer of the Privy Council) where refuse matters are removed more speedily than they were formerly, the general death-rate has been lessened. The chief improvements that have been made in these conservancy systems, consist in diminishing in various ways the size of the receptacles, so that the refuse matters cannot be collected in so large an amount, or kept for so long in and near the house, and in making the receptacles impervious to water, so that liquids cannot escape from them into the soil around, nor water get into them. Sometimes the receptacles are drained into the sewers so that the liquid part can run away leaving the contents of the receptable drier. In other cases they are not. The improvements in cess-pools, then, have consisted in making them smaller and smaller and, lastly, moveable—the *fosses mobiles* of the Continent; the pans, pails, tubs, &c., of some of our large towns. These moveable receptacles are placed underneath the seats of the closets, fetched away when full by the scavenger, and replaced by the empty ones. They are, or ought to be, fitted with air-tight lids, so that as little nuisance as possible may be caused by carrying them to the carts; but as may be expected, in many instances they are allowed to get too full, and a great nuisance is often caused in the houses. Nevertheless, this plan is a considerable improvement upon the plan of large buried cesspools. One of these pails that is largely in use is Haresceugh's spring-lid receptacle, a specimen of which may be seen in the Parkes Museum.

Similar improvements have been made in middens. The pits, in which the excretal matter and ashes are collected, have been made smaller and smaller, and impervious to water, until at last, in some towns, they are above the ground, and consist only of the space beneath the seat of the closet made into an impervious receptacle, and usually drained into a sewer or drain. This, of course, necessitates their being emptied frequently, which is done by hand and spade labour. A capital plan is that adopted by Dr. Bayliss, the Medical Officer of Health for the West Kent Combined Districts, in which there is a ventilating shaft from the back part of the receptacle rising above the roof, of the closet. This allows the foul air to escape above the roof, while fresh air enters through openings cut in the door. Sometimes boxes or pails are used and removed periodically, as in the case of tubs and pails, previously described as moveable cesspools, the only difference being that ashes, &c., are thrown in with a scoop or by means of some self-acting apparatus. A contrivance which is now largely used, in towns where this system is in vogue, is Morell's cinder-sifting ash-closet, of which a specimen may be seen in the Parkes Museum. The ashes are thrown on to the sifter, through the interstices of which the fine ash passes into a hopper, and the cinders fall off and may be collected and used again. The hopper is connected with the seat in such a manner that the weight of the person moves the seat a little and jerks some of the fine ash down into the lower part of the hopper, from which it is thrown into the midden by another jerk when the person rises. Another contrivance of this kind is Moser's, which is also of very simple construction, and others are Taylor's and Weir's. The Eureka and Goux, and some other systems are varieties of the pail system in which an absorbent of some kind or another is used.

We now come to the consideration of the dry-earth system, which was brought into prominence by the Rev. Henry Moule. It consists in throwing over the excretal matters a certain quantity of dried and sifted earth, when an absorption takes place, and a compost is produced which is perfectly inoffensive to the sense of smell. The earth may be dried and used over and over again for five or six times or even more, and any earth except chalk or sand will answer the purpose. It may be thrown by hand, or by a self-acting apparatus moved by the weight of the person, or by the door of the closet, or by a pull-up apparatus similar to that ordinarily used in water-closets. It will be seen at once that with this system there is not only something to be taken away, but something to brought into the towns and into the houses—the dried earth; and this constitutes a very serious objection. However, it is an objection that might perhaps be waived, if the system could be satisfactorily worked on a large scale and by careless persons, for it is essential, in a large town at any rate, that a system for the removal of refuse matters must be used which can be worked by the most careless persons. When we consider that, if the supply of earth were to fail for a day, a serious nuisance would be caused in every house; that if a servant throws a pail of slops into the earth-closet it becomes a cesspool; that the apparatus may get out of order, so that earth is not thrown in even though the hopper be full; and that an enormous quantity of earth would be required in every large town, we shall see that, at any rate for large towns, it is impracticable; and when added to this, we find the fact that one great argument in favour of the system, the supposed value of the manure produced, is entirely fallacious, it having been shown by the Sewage Committee of the British Association, that the compost, even after passing six times through the closets, can only be regarded as a rich garden soil, and would not pay the cost of carriage even to a small distance; that in fact in the disintegration and decomposition of the organic matters that takes place in the mass, almost all the nitrogen is got rid of in some way or another, we see that one great argument for its use in towns disappears. We must remember, too, that deodorisation is not necessarily disinfection, and, as Dr. Parkes pointed out, we do not know that the poisons —say of typhoid fever and cholera—are destroyed by being mixed with dried earth. It is even possible that they are preserved by it, and there can be no doubt that if the earth is not sufficiently dried, or if water is thrown on the mass, considerable danger would arise if the poisons of such diseases were present. While, however, the system is impracticable for large communities, it is one that has been found very useful indeed under suitable circumstances. It is useful for temporary large gatherings of people at flower shows, cattle shows, race meetings, volunteer reviews, &c., especially where there is supervision, and where persons can be told off to attend to the distribution of the earth. Earth-closets are suitable for use in villages and country houses in the open air, but they ought not, in my opinion to be placed indoors even in the country. Where the earth can be collected and dried on the spot, and the compost afterwards used upon the garden, the plan has been found very useful if only sufficient care be exercised, and no nuisance need be produced.

To sum up with regard to the conservancy plans, their very name condemns them one and all, for use in large towns at any rate, or in the interior of houses. One of the most important of sanitary principles is, that the refuse matters should be removed as speedily and as continuously as possible from the neighbourhood of habitations, and the principle of all conservancy systems is that the refuse matters are to be kept in and about the house, at any rate as long as they are not a nuisance, which of course means that, in a large number of cases, they become a serious nuisance. It is also obvious that the carriage of the refuse matters entails considerable cost under any of these systems, and so the less frequently they are removed the less does it cost, and what is detrimental to the life of the population becomes advantageous to the ratepayers. If the manure so collected were valuable, it might, of course, be made to pay the cost of collecting, but this is not the case as a rule, the only instance in which any of these systems have been made to pay being where the excretal matters have been collected in pails or tubs, unmixed with anything which would lessen their value. With all these systems, too, it is necessary to have some method for disposing of the slops and foul water generally, which cannot be allowed to run into the water-courses, as it would contaminate them, and so it is necessary to have sewers, the construction of which will be described in the next lecture.

As opposed to the conservancy systems, we have the water-carriage system, by means of which the refuse excretal matters are conveyed away in the foul water by gravitation through the sewers, and are thus removed from the houses as speedily and cheaply as possible by means of the pipes, which must in any case be provided in towns, to get rid of the foul water. The sewage is increased in bulk, but is not rendered perceptibly fouler by this admixture. Indeed, as a rule, the sewage of a town supplied with water-closets is less foul than that of a town supplied with middens. Although, however, sewers are necessary in towns to carry the foul water away, in country places the slop water may be allowed to run into the surface drains, provided they do not pass near wells, and this is best managed by means of a contrivance which I shall describe in another chapter.

The water-carriage system has disadvantages of its own, and requires special precautions to be taken, which so far as they are connected with dwelling-houses, will be described in the next two chapters.

CHAPTER V.

Sewerage—Main Sewers and House Branches, Traps, Ventilation, &c.

Even where conservancy systems are used for the removal of refuse excretal matters, it is necessary to have some contrivance by means of which the foul water can be got rid of. In country places, it may be discharged into ordinary agricultural drains laid beneath the garden. It then percolates into the soil and serves to fertilise the crops. If, however, such waste water is thrown gradually down the traps and into the drains a small quantity at a time, the water escapes through the junctions of the first few pipes, and the fat and other solid matters become deposited in them, and soon choke up the pipes; so that it is necessary to collect the slop-water, and discharge it at intervals. The best contrivance for this purpose is Mr. Rogers Field's flush tank; the slop-water is discharged over a loose iron grating at the top, and passes through a funnel-shaped aperture with a syphon bend at the bottom of it, which can also be lifted out, into the tank below. The discharge-pipe from this tank does not start from the top of it, but very near the bottom, is carried upwards to the top and turns over and passes downwards to its outlet, which is at a lower level than the point from which the pipe began. This pipe is made in the earthenware end of the tank itself. Thus it will be seen that a syphon is produced, so that when the tank is filled to the top, and the shorter limb of the syphon also filled up to the bend, a sufficient quantity of water thrown in suddenly will start the syphon, and so empty the tank of its contents to the level from which the lower limb starts inside the tank. The discharge end of the syphon has a weir placed across it with a notch in it. By means of these contrivances, not only will a smaller quantity of water start the syphon, but a false action which was found occasionally to take place, and which caused the water to dribble away without the tank being emptied, is prevented. Thus the whole body of water contained in the tank is made to rush through the drains, and the difficulty spoken of above is avoided. The tank also acts as a very good fat trap. In towns, however, it is necessary to have sewers for the removal of the foul water. Sewers ought to be impervious to water, so that their contents may not percolate into the soil around, and so drains which are made to dry the soil are obviously not fitted to be used as sewers. The larger sewers are usually made of bricks, and built with an oval section, this being preferable to the circular, and of course far better than any rectangular section. The bricks should be of the very hardest kind, and set in cement, and it is advisable to build the "invert" or lower part of the sewer, upon invert blocks made of stoneware. For smaller-sized sewers stoneware pipes are the best. They should always be used for sewers not greater than 18 inches in diameter. Larger sewers than these are cheaper made with bricks set in cement. Stoneware pipe sewers would be much more used than they are in towns, but for the fact that the estimated size of the sewers generally is usually larger than is required, and much larger than would be required if the rain and surface water were carried away by separate drains. The pipe of the sewer only requires to be large enough to carry away the water that can be discharged into it, and anything beyond that size is an absolute disadvantage, as it makes it more difficult to flush the sewers properly, for a larger pipe is insufficiently flushed by a quantity of water that would easily flush a smaller one. For flushing purposes it is best to have an arrangement by which a considerable quantity of water is delivered into the sewer at once, so that it may fill it, or nearly so. The same quantity of water delivered more gradually does not produce by any means the same effect. In laying sewers whether main or house sewers, provision should always be made for making new connections without cutting into the pipes. This may be done by putting in junctions at various points—a plan especially suited for private estates, where the points at which junction may be wanted will suggest themselves. With street mains more ample provision should be made. Mr. Jennings's pipes, which allow the sewers to be opened at any point without cutting the pipes, may be used. The pipes in fact, have no sockets, the place of the socket being supplied by divided rings, in one half of which the pipes are laid at their junction while the other half covers the upper part of the junction. With ordinary socket pipes, Messrs. Doulton's lidded pipes may be used with advantage. In these a third of the pipe can be taken off along the whole length of the pipe, so junctions can be made, the pipes inspected, and cleaning rods pushed down them when necessary. The "capped" pipes made by Messrs. Jones and Company, of Bournemouth, are also useful. They are constructed in the following way: a semi-circular or semi-elliptical hole is cut out of each pipe at its end, so that when the pipes are socketed a circular or elliptical hole is left at the junction between the two. These holes are closed by means of lids made for the purpose which may be removed at any time, for the purposes of inspection, inserting a junction, &c. The above remarks apply to house branches as well as to main sewers, and it is very important not to omit the insertion of inspection pipes, of some kind or another at proper intervals and suitable places, in house sewers, especially those of large mansions.

The main sewers should be freely ventilated at the level of the streets. All attempts to ventilate them in any other manner have been, without exception, signal failures. If the ventilators, whether of main or of branch sewers cause a nuisance, it is because there are not enough of them, or because the sewer is either badly laid or not properly flushed. In country places especially, cesspools are often the destination of the house sewers. Cesspools should never be made where it can be helped. It is far better to use the sewage on the land than to collect it in cesspools. However, in some places, cesspools are necessary, in which case they should always be made impervious to water, by being built of bricks set in cement and rendered in cement.

The cesspool should not be under the house, but at some distance, and it must be ventilated. If near to the house, the ventilator should be carried up outside the wall of the house, and above the ridge of the roof. If at some distance, it may be ventilated either by means of an open galvanised iron grating, or by means of iron pipes carried up a tree and covered with wire network at the top. The cesspool should not overflow into a stream, or drain running into a stream, but on to the surface of the ground; and it is folly to build a second cesspool, as some people do, for the first one to overflow into, for, by the same argument, one might build any number—one after the other. Brick sewers should never be used under houses. The foul water soaks through them into the soil, and sediment is liable to accumulate in them. Rats eat their way through them, displacing the bricks and wandering about the house, and so not only does foul water get out of them into the soil, but foul air finds its way wherever rats go, besides the fact that rats carry filth from the sewer itself about the house, and into the larder if they can get there. In this way I have no doubt whatever, that milk and other foods have disease poisons frequently conveyed to them. Sewers made of glazed stoneware pipes should always be used for houses, except in cases where it may be better to use iron pipes, and they should always be laid outside the walls of the houses whenever it is practicable. They should be laid in a bed of concrete if there is any reason to fear a settlement of the ground, or in very wet soils on hollow invert blocks. They should be jointed with cement, but outside houses where a slight settlement is feared, they may be jointed with clay, finishing with a ring of cement. Clay alone is not advisable, as it is apt to get washed out of the joint, in which case the water runs into the soil, and the solid matters accumulate in the sewer. If pipes, with Stanford's patent joint are used no cement is required. The ends merely have to be greased and fitted into one another. These pipes must be laid straight, or they will not fit together, and at bends it is often requisite to use ordinary socketed pipes. The fall of a house sewer should be at least 1 in 48, but a more considerable fall is preferable; 9 inch pipes may be used for very large mansions especially if outbuildings are connected with the sewer, but, as a rule, for private houses 6-inch pipes with 4-inch branches are amply large. The junction of the branches should never be made at right angles, but always at an acute angle, and of course in the direction in which the water is going. At the end of the house sewer, in the main sewer or cesspool, a swinging flap made of galvanised iron is frequently placed, with the view of keeping rats out of the house sewers. It may be of some use for this purpose but is of little use for preventing the entrance of foul air, and, as may be expected, these flaps are often out of order. It is also usual to place a water-trap of some kind upon the house sewer before it enters the main sewer or cesspool. The kind formerly most used was what is known as the dipstone trap. The drain was deepened at the spot, and a piece of stone or slate inserted right across the drain from side to side, and reaching from the top down into the deepened part two or three inches below the level of the bottom of the sewer. Water of course always remained in the deepened part, and so the dipstone running right across the drain dipped about two or three inches into this water. As it reached also to the top, and was built in, it obviously prevented the passage of the sewer air from the main sewer or cesspool into the house sewer, except that which could pass through the water in the trap. These traps were usually made rectangular, and were often very large, so that they were practically cesspools, and they still go by this name in some parts of the country. They may be much improved by making the end nearest to the house vertical, giving the opposite one a gentle slope, and fixing the dipstone not vertically, but slanting in the direction in which water goes—rounding off the inside with concrete rendered in cement, so that there are no angles or corners. Thus the water falls vertically into the trap and flows out through a gentle incline. In such a trap very little accumulation occurs. Stoneware syphon traps are, however, now almost entirely used. They are frequently made with an upright piece from the lowest part of the syphon, which may be continued by means of straight pipes up to near the surface of the ground, for the purposes of inspection, and of cleaning out the syphon should it get blocked up. This inspection opening is now sometimes made at the end of the syphon which is intended to be placed next to the house, so that if pipes are carried from it up to the surface of the ground, and an iron grating put on to it, a passage is formed which, under ordinary circumstances, acts (if precautions are taken which will be presently mentioned) as an entrance for air into the house sewer. The syphons also are now made with the limb into which the house sewer opens nearly vertical, while the opposite limb has a gentle slope upwards—the effect produced being that already mentioned. It is a considerable improvement, although not absolutely necessary, to increase the air inlet into the sewer at this point, that is to say, on the house-side of the syphon trap, and instead of merely having a pipe taken up to the surface of the ground, to have a man-hole built in brickwork, and with channel pipes instead of whole pipes running along the bottom of it into the syphon. The channel pipes and one or two pipes beyond should be laid at a considerable fall, so that the water may rush down into the syphon and clear it out as much as possible. Branch pipes may be made to join the main in the man-hole by means of channel pipes, or even by whole pipes discharging into a gutter built above the channel pipe; or they may of course be taken into the house sewer at any point of its course. The man-hole may be covered by a galvanised iron locked grating, if it is in such a position that gravel, &c., is not likely to get into it, but if in an area it is better to cover it with a locking iron door, and to have one or two 6-inch ventilating pipes from its upper part carried under the pavement to the area wall, up in the wall a short distance, and then opening out by gratings flush with the surface of the wall. A junction pipe should be fixed immediately beyond the syphon and pipes brought from it through the wall of the man-hole, the end being filled with a plug which can be removed for the purpose of cleaning the sewers beyond the syphon if necessary.

Or various stoneware disconnecting traps may be used: Potts's Edinburgh chambered sewer trap has the advantage of having a large air inlet, and a considerable fall in the trap itself; in many instances, with sewers already laid, sufficient fall cannot be got to introduce this trap. Weaver's trap is really a syphon with an upright air inlet leading into the limb of the syphon nearest to the house. Beyond the syphon an aperture is provided by means of which the main sewer or cesspool beyond, can be ventilated, or which, if merely plugged, may serve as an inspection pipe, through which rods can be pushed, if neccessary down into the main sewer or cesspool. In Buchan's and Latham's traps the fall is quite vertical. Stiff's interceptor may be described as a syphon-shaped trap, with a double dip, so that it has three compartments, with an open grating for the middle one. If any sewer air should pass under the first dip, it cannot get under the second, which is deeper, but will escape into the open air through the grating. Two inspection openings are provided, which may be also used as ventilating openings—the further one to ventilate the main sewer or cesspool, if necessary at this point, by means of a pipe running to the top of the house, and the one on the house side of the trap may be used as an air inlet. Professor Fleeming Jenkin has introduced the plan of using two syphon traps with an open grating between them. Dr. Woodhead has modified this by having a large stoneware receptacle, which the house pipes enter underneath a large iron grating, with two syphons beyond the receptacle, one after another, and an upright pipe with an open grating between them. There is also a smaller upright pipe with open grating at the top between the receptacle and the commencement of the first syphon. It is unfortunate that we cannot do without a water trap at all in disconnecting the house sewers from the mains, and I certainly do not think that any sufficient reason has been made out for having two traps one after another.

At the highest point of the house sewer, (or, if necessary, at the ends of two or more branches,) there should be a ventilating pipe, four inches in diameter, carried up above the eaves of the house or above the ridge of the roof, and not under or near any bedroom windows. This may be covered with a little conical cap or merely with a piece of wire network, or with a cowl (preferably a fixed cowl) if it is required to be ornamental. Whether this pipe be covered with a cowl or not, air will as a rule, enter at the air inlet at the lower end of the sewer, pass along it through its whole length, and escape by the ventilating pipe or pipes just mentioned, and no foul air can accumulate in any part of the sewer. If any foul air escapes at the air inlets, it acts as a warning to show that something is wrong; the syphon is stopped up, or there is an accumulation of foul matter in it, or in the sewer, somewhere. When all is going right, no foul air will escape by these openings. The ventilating pipes may be made of iron if only used as ventilating pipes. When used also as soil-pipes they are better made of lead, as will be further shown in the next lecture. Rain-water pipes may be taken directly into the house sewer or its branches without any trap, provided that their joints are well filled and packed, and that they do not open at the top near to any bedroom windows, otherwise they must discharge over the surface of the yard or area. The surface gulleys for yards, &c., may be stoneware syphon gulleys, provided with galvanised iron gratings, which are better than stoneware gratings and are less liable to break. They are sometimes provided with openings in the side above the level of the water for the admission of waste pipes, &c. Dipstone traps are sometimes used, but are objectionable. McLandsborough's gulley is sometimes useful; it may be described as an iron dip-trap with three compartments, having several openings, into which pipes may be taken above the surface of the water. Jennings's receiver is also often useful, especially where the trap has to be low down, and upright pieces placed one above another over it up to the level of the pavement. Pieces with openings are provided, so that drains coming from the inside of the house—the basement drains for instance—may be discharged into it, and so disconnected from the house sewer. Drains from the basement of a house ought not to open directly into the house sewer, but always into a disconnecting trap of some kind or another. Clark's gulleys are useful where much sludge is likely to be washed into the trap. They are provided with iron buckets that collect the sludge and can be lifted out bodily. They are doubly and sometimes trebly trapped. The common bell trap, so often used not only in areas but in the basements of houses, is a most mischievous contrivance. It consists of an iron box with a pipe, which is connected with the sewer, standing up in it. The perforated cover of the box has an iron cup or bell-shaped piece fastened underneath it. Of course water stands in the box up to the level of the pipe which descends into the sewer. The bell on the perforated lid is so arranged that when the lid or grating is in its place, the rim of the bell dips into the water around the vertical pipe. Even if the bell is in place, and whole, the trap is untrustworthy, because a very slight increase of pressure of air in the sewer will cause it to force its way through the small film of water into which the bell dips. It is objectionable because it soon becomes filled up with filth, and because, unless water is almost continually running through it, a sufficient amount evaporates to allow the sewer air to escape freely; but the great objection to it is that, when the cover is taken off, the bell is taken off too; the trap, such as it is, is gone, and the air from the sewer escapes freely into the house if the trap is inside the house. The covers are often taken off by servants, and left off, and are also frequently broken, and so the use of these traps should be discouraged as much as possible. The Mansergh trap is frequently useful in areas, as it serves also for the disconnection of the basement sinks, and provides a place of attachment for a ventilator for the house sewer. It consists of three compartments; into an opening in the side of the first, the waste pipe of a sink may be conducted; the water from this fills the first compartment up to the level of an aperture, through which it passes into the second, the pipe through which the water is conveyed into the first compartment being made to dip below the surface of the water in that compartment. Over the first and second compartments there is a loose iron lid with a grating over the second or middle compartment. From the second compartment, the water passes under a partition into the third, the outlet from which into the house sewer is above the lower edge of the partition, which itself extends from the top of the trap nearly to the bottom, so that it completely separates the air in the third compartment from that in the second, and dips beneath the level of the water in the two compartments. The top and sides of this third compartment are made of stoneware, so that it does not communicate with the external air, the outlet to the sewer being at one side, and an aperture to which a ventilating pipe may be attached in one of the other sides. Even if the last aperture be plugged up, and no ventilating pipe attached, any sewer air which can pass through the water from the third compartment into the middle one would escape by the grating into the open air, and could not get into the house, as the pipe from the house into the first compartment of the trap dips below the water. The cases in which it is more advisable to use this trap than ordinary syphon gulleys, will be mentioned in the next chapter.

CHAPTER VI.

Water-closets, Sinks, and Baths.—Arrangement of Pipes, Traps, &c.

Water-closets.—The simplest form of water-closet is the common hopper closet, consisting of a conical basin with a stoneware syphon trap below it. There is nothing to get out of order in these closets, but they are liable get stopped up through an insufficient amount of water being used in them, and the basins often get very foul from the same cause, and from the fact that no water remains in the basin. They are very often supplied with water by means of a $\frac{3}{4}$-inch service pipe, which cannot supply enough water to flush them properly. This pipe is frequently taken directly from a cistern supplying drinking water, or even, where the water service is constant, directly from the main water pipes, provided with an ordinary stop-cock, or, perhaps, with a screw-down tap—a very mischievous plan, as the taps are frequently left turned on, and the water allowed to run to waste, sometimes emptying the cistern, and allowing foul air to get into it. When such pipes are taken direct from the main, the results are even more serious, as, if the water is, for any reason, turned off in the latter, foul air, and even liquid and solid filth, may be soaked up into the water mains and contaminate the water supplied next. To this cause a very serious outbreak of typhoid fever in Croydon has been traced by Dr. Buchanan. The supply pipes for these closets should not be less than 1¼-inch in diameter, and should not be connected directly with the drinking water cistern or with the main water-pipe, but with a water-waste preventing cistern holding two or three gallons—(the quantity required to flush the closet) and supplied from the nearest water cistern, or in the case of constant supply, from the main water-pipe—the supply pipe being guarded by a ball valve. The pipe from this waste preventer to the closet is guarded by a valve, frequently the conical one known as the spindle valve, which can be raised by means of a lever worked by a chain and ring. When the chain is pulled, the spindle valve is raised, and the two or three gallons contained in the water-waste preventer are discharged into the hopper closet, while at the same time the ball valve is also raised by the lever, so that no water can come into the waste preventer while the chain is being pulled. It will be seen that this and similar contrivances not only prevent direct connection between the water-closet and the drinking water of the cistern or main water pipe, but also prevent an inordinate waste of water. Instead of the spindle valve in the water-waste preventer it is better to have a regulator valve, such as will be described shortly, under the seat of the closet. An improvement on the ordinary hopper closet is the "Artisan" closet, made by Messrs. Beard, Dent, and Hellyer, in which the hopper is provided with a flushing rim, which is far better than the old plan of shooting the water in at one side of the hopper. In the "Vortex" closet, made by the same firm, the syphon is much deeper than in the "Artisan" closet, and the water stands in the basin. A two-inch supply pipe is necessary, the water being discharged by a flushing rim, and also projected into the middle of the basin, as it is clear that a greater force of water is required to flush out so deep a syphon. On the other side of the syphon is placed a ventilating pipe to carry away any foul air.

We now come to various forms of "Wash-out" closet, the first being Jennings's "Monkey" closet. In this a small amount of water remains in the basin, the opening out of which into the syphon is not at the bottom, as in the case of the hopper closet, but on one side. The advantage of this form of closet is that it is not possible, as is the case with hopper closets, for careless persons to go on using the closet without flushing it with water, as the soil remains in the basin until it is flushed out. Hopper closets, on the other hand, may be used for a long while without any supply of water at all, and this is the way in which pipes get stopped up. In the monkey closet the basin and syphon are all in one piece of earthenware. In Woodward's "Wash-out" closet the basin is provided with a flushing rim, and the syphon is separate from the basin, so that it can be turned in any direction necessary. In Bostel's "Excelsior" closet the basin and the syphon are one piece of earthenware, and the outlet is at the back of the basin. The water-supply pipe is made to enter the basin by two branches, one on each side, and a flushing rim is provided. At the back of the basin is a vertical opening leading directly into the syphon, by means of which anything improperly thrown into the closet can be removed. An overflow-pipe is also provided, but this is, in most instances, useless. Dodd's "Wash-out" closet is somewhat similar in shape to the others, but has a ventilating pipe attached to the discharge pipe immediately beyond the syphon. An inch and a quarter supply pipe should be used in these closets, and where there is less than six feet fall, 1½-inch pipes may be used with advantage. Fowler's closets are suitable for use in poor neighbourhoods, especially when there is an insufficient supply of water. In this system, rain, sink, and other waste waters are made to wash out the trap of the closet.

The closet apparatus most commonly used in the interior of houses is that known as the "pan" closet, and is a most mischievous contrivance. The basin is conical, and below it is placed a metal pan capable of holding water, into which the lower part of the basin dips. This pan can be moved by the pull-up apparatus of the closet inside a large iron box called the "container" placed under the seat of the closet, and into the top of which the conical basin is fixed. This "container" has a 4-inch outlet at the lower part of it leading into a trap placed below the floor, the trap being generally a lead "D" trap, from which a 4-inch pipe passes to the soil pipe, which conveys the refuse from the closets into the sewer. The great fault of the "pan" closet consists in the large iron "container," which is merely a reservoir for foul air, as it always becomes very filthy inside. When the pull-up apparatus is worked, the pan is swung from its position below the basin, and its contents thrown into the "container," the sides of which are splashed with foul matters, and cannot possibly be cleaned. Besides this the container leads into the D-trap, which always contains foul matters, and gives off foul air into the container. At the same time that the contents of the pan are thrown into the container, foul air from the latter is forced into the house. This can only be partly remedied by providing a ventilating pipe for the container, and carrying it out of doors, but I have more than once seen a ventilating hole drilled in the container, and no pipe attached to it, so that foul air from the container was driven out, with a puff that would blow out a candle, each time the closet was used, and this in closets immediately connected with bedrooms. The D-trap should not be used at all either under closets or sinks. It consists of a lead box shaped like the letter D, placed thus, . The outlet pipe starts close to the top at one end, and the inlet passes down to an inch or so below the level of the lower part of the outlet. Of course water remains in this trap up to the level of the outlet, so that the inlet pipe dips into it an inch or more. The D-traps are never washed out thoroughly at each use of the closet. A deposit of foul matter takes place in them, and foul air is generated. This gradually corrodes the lead, and eats holes through it at the upper part of the trap. In the Parkes Museum are many specimens of D-traps with holes eaten through them by the foul air. Such holes, of course form a means of escape for the foul air from the sewer into the house. The trap is generally made of sheet lead, and not cast in one piece of lead; but an improved form has been made by Messrs. Gascoyne, which is cast in one piece, and in which the inlet pipe is placed at one end, so that there is no space left between it and the end of the trap, for paper &c., to accumulate in. Instead of a D-trap, where a lead trap is used, it should be an S-trap or P-trap of 4-inch cast lead. This is flushed out by each use of the closet. A lead tray is usually placed on the floor underneath the closet apparatus, the trap being placed sometimes above and sometimes below it. The object of this tray is to prevent any overflow from the closet soaking into the floor and often through into the ceiling below, causing serious annoyance, and perhaps a great nuisance. This tray is commonly called the "safe" of the closet, but as generally constructed, any other word in the language would be more applicable to it. It is, of course, provided with a waste pipe, and this waste-pipe is almost invariably carried into the D-trap, when there is one below the safe, but it is not unfrequently carried straight into the soil-pipe, with or without a syphon bend on it. When carried into the D-trap, it is usually made to enter below the surface of the foul water therein contained, but I have not unfrequently seen it carried straight into the top of the trap, so forming a passage for foul air into the house. It ought not to be connected with any part of the water-closet apparatus, trap or soil-pipe, but ought to be carried straight through the wall to end in the open air, being merely provided with a small brass flapper to keep draughts out. The waste or overflow pipes of cisterns, are frequently carried into the D-traps of closets, in which case foul matters get washed into the inside of these pipes, and foul air from them contaminates the water in the cisterns. This is even a greater evil than the last, and the waste pipes of all cisterns, but more especially those used for the supply of drinking water, should, as stated in a previous lecture, be made to end in the open air.

We come now to valve closets, the numerous varieties of which are modifications of the original Bramah's valve closet. In this the aperture at the lowest part of the basin is closed by a water-tight valve, which can be moved in a small valve box, placed immediately below the basin, by means of the pull-up apparatus—the valve box itself being connected below with the trap. Thus, the necessity for the large iron container, so objectionable a part of the pan-closet, is done away with, and its place taken by a small box, in which the valve moves. As, however, the valve is water-tight, provision is made for the overflow of water from the basin, in case the latter should be filled too full, either by slops being thrown into it, or by the water continually running from the supply-pipe in consequence of a leaky valve. The overflow pipe starts from one side of the basin in which holes leading into it are perforated. It is then as a rule, carried downwards into the valve box, having a small syphon bend on it before entering. The water from the supply-pipe, as it enters, is made to flow round the basin by an inner plate, generally made of metal, called the "spreader," or still better, in the improved form of valve-closet, by means of a flushing rim. Thus, some of the water at each use of the closet passes through the holes leading into the overflow pipe; the object of this being to keep the syphon on that pipe charged with water, as it is clear that if this syphon is not charged, the overflow pipe ventilates the valve box, that is too say the space between the valve and the surface of the water in the trap below, into the basin of the closet. Now, as a rule, the syphon trap on the overflow pipe does not remain charged with water, and even if it does, is of little use, for the following reasons; —when by the pulling up of the handle the valve is made to move suddenly in the valve box, air from the latter is forced out through the water in the syphon bend of the overflow pipe, as any one can see, who will take the trouble to place a piece of moist tissue paper over the holes in the side of the basin leading into that pipe, and then work the handle of the closet; thus foul air from the valve box is driven into the basin, even when the syphon on the overflow pipe is charged. Furthermore, as the mass of water in the basin rushes down through the valve box into the trap it carries the air along with it, and when the valve is closed runs out of the valve box, drawing air through the overflow pipe, and displacing the water in the syphon, which is in many cases left quite uncharged. Various remedies have been proposed for this. In Bolding's "Simplex" valve closet a small pipe is carried from the water-supply pipe into the overflow just above the the syphon, with the view of supplying water direct to the syphon each time the closet is used. In Jennings's valve closet the overflow is trapped by means of a patent india-rubber ball trap, which is something like a Bower trap upside down. It is constructed so that the overflow water can displace the ball from the end of the water-pipe and flow away around it, but any pressure of air from the valve box would only cause the ball to fit more closely against the end of the overflow pipe. In the valve closet made by Beard, Dent, and Hellyer, the overflow pipe is made much larger than usual, and the syphon deeper, so that it holds a larger quantity of of water, and at the same time a ventilating pipe is inserted into the valve box and should be carried through the wall to the outer air. By this means no accumulation of foul air in the valve box can take place, and any air that is drawn into it, while the water is passing through it, comes in through the ventilating pipe instead of through the overflow. It is quite right to ventilate the valve box, but the best way to deal with the overflow pipe is to disconnect it altogether from the valve box, and either carry it through the wall placing a brass flap on the end of it, or let it end over the waste pipe of the safe. Indeed, it is hardly necessary to have an overflow pipe at all, as if the basin does get full, all that will happen is that the water will flow over the top of it into the safe and run away. The advantage of this plan is that the existence of a leaky valve is found out immediately, and the disadvantage is that it is liable to wet the end part of the seat and apparatus below it. Lead D-traps are generally placed under these closets, but this should never be allowed. Syphon traps should always be used, for the reasons already mentioned. Some valve closets are made with a galvanised iron syphon trap that is to be placed wholly or partially above the floor, and is provided with a screw cap that can be taken off for the purpose of cleaning; such closets are made by Messrs. Tylor and Sons, and Messrs. Jennings. The latter also make closets, which may be called "plug" closets, the best known variety having the basin and syphon trap all in one piece of china. The plug closes the entrance from the basin into the syphon below, and is connected by a rod with the handle, which is vertically over it. By means of an india-rubber flange the plug is made to fit water-tight into the entrance of the syphon, and a body of water is kept in the basin above it, up to the level of the overflow, which is either made through the plug and the rod joining it with the handle or by a separate trapped channel alongside of it. A plug is also made to contain the patent ball trap mentioned above. It will be seen that in these closets, no valve box is necessary, and there is only a small air-space between the water in the trap and that in the basin. These closets are also made without any trap at all, in which case the overflow of the basin is carried, by a pipe, straight through the wall. Such trapless closets are often very useful on the ground floor, where the soil pipe can be carried straight through the wall and disconnected from the sewer by a ventilating trap outside.

We must now consider more in detail the arrangements for the supply of water to the basin. The simplest form of water-waste preventer has already been mentioned, but it must be remembered that the commonest plan for supplying closets with water, is to place a spindle valve in the bottom of a cistern somewhere above them, so as to guard the entrance into the pipe leading to the basin of the closet, and to work this valve by means of wires connected with the pull-up apparatus. The great disadvantage of this apparatus is that the wires get stretched by use, and have to be shortened from time to time. There is, obviously, also no provision against waste of water, for the water will run as long as the handle is held, or fastened up, until the cistern is empty. Neither is there any "regulator" to ensure a sufficient supply of water being delivered to the closet each time that the handle is pulled up, whether it is held up or not. Waste-preventing valves have been devised to effect these objects. When the handle of the closet is worked the valve is raised, and if the handle is let go, the valve does not fall directly but gradually, so as to allow a certain quantity of water to flow into the basin of the closet. But if the handle is held up (or down in case of a ring and chain) a metal weight which was carried up with the valve falls, and stops the flow of water. These valves may be used in cisterns, and connected with the pull-up apparatus by wires, or they may be placed in the small waste-preventing cistern already described, with a view of ensuring the use of a definite quantity of water each time. In another of these waste-preventing cisterns the pipe supplying the closet does not start from the bottom, but starts inside the cistern in the form of a syphon which is so arranged that when the water is once started it all runs off. Another waste-preventer which can be seen in the Parkes Museum, has been recently invented by Mr. Jennings, jun., and consists of a heavy metal cylinder with a piston inside it, the rod of which is the rod to which the handle of the closet is fixed. Upon this cylinder are two projections, one of which lifts the lever which turns on the water, and the other one which moves the valve. The piston is made so large that the cylinder adheres to it, and when the handle is pulled up the cylinder is therefore, lifted with it, and the valve opened and the water turned on at the same time, but if the handle is held up too long the weight of the cylinder gradually overcomes its adhesion to the piston, and it falls, closing the valve of the closet and turning off the water at the same time. Thus, this water-waste preventer does not come into action at each use of the closet but only when it is wanted. Not only water-waste preventers, but regulator valves are used in all the best forms of closets. There are as already hinted, valves that are so constructed that they allow a certain quantity of water to pass through them whether the handle of the closet be held up or not, so that the proper quantity of water is supplied even if the handle is pulled up and let go at once. The oldest and best known of these is Underhay's regulator valve. The valve itself is, of course, worked by a lever, and the rate at which the valve is closed depends upon the rate at which the lever falls. This rate is regulated by the fall of a piston in a cylinder, the escape of air from which can be controlled by means of a small tap, so that the rate at which the lever will fall and close the valve, and, therefore, the quantity of water which will pass into the basin each time that the handle is pulled up, can be regulated to a nicety. The commonest form of this regulator is known as the bellows regulator. Other regulator valves are Tylor's and Jennings's, in which, by means of simple arrangements, the rate at which the lever falls and closes the valve can be controlled. When water is delivered on the constant service at high pressure, Common's waste preventer is sometimes used. In this the requisite quantity of water is collected under pressure in an iron cylinder, the air in which is compressed by the pressure of water from the main. When the handle of the closet is pulled up, it moves a valve, which closes the pipe from the main, and opens that leading into the basin of the closet. The compressed air in the cylinder then expands, forcing the water before it into the closet, and no more water will come in from the main until the handle is put down again, when it can only flow into the cylinder, and not into the closet. Vessels containing disinfectants or deodorandants are sometimes attached to closets in such a manner that a certain portion of disinfecting or deodorising fluid is thrown into the water in the basin each time the closet is used; but, if closets are properly constructed, this is not necessary.

We next come to the soil-pipe, which conveys the waste matters from the water closet to the sewer. Soil-pipes are most frequently made of lead, and they should as a general rule be 4 in. in diameter. Formerly, when made of lead, they were necessarily seamed pipes, as drawn lead pipes were then unknown. Consequently there were not only soldered joints at the ends of the lengths, but a soldered seam longitudinally the whole length of the pipe. These seamed pipes should never now be used, and where found should always be taken out, as the seam gives way sooner or later, even when the pipe is placed quite vertically, and it then allows foul air to escape into the house. Pipes of drawn lead should be used, so that the only joints are at the ends of the lengths, and these can be made, and are commonly made, more durable than the pipe itself, which is not the case with the seamed joints. Iron soil-pipes are sometimes used, and, indeed, are preferred in climates where there are great variations of temperature, as they expand and contract less than lead ones do. But in this climate drawn lead soil-pipes are preferable, especially if they are placed, as they frequently are, inside houses, in which position I should never allow an iron one to be fixed, on account of the difficulty of being sure that air-tight joints are made; and even outside a house lead ones are to be preferred although more expensive, because when iron ones are used, it is usually necessary to put lead pieces in to receive the lead pipe from the closet, to prevent a joint between lead and iron being made inside the house, and however carefully this is done, it always looks like a patched-up job. When lead pipes are placed outside houses, it is, however, necessary to have them cased to protect them from mischief or violence. The small additional expense is of little consequence, and it is best to have them cased throughout their entire length with galvanised iron. In order that they may not project too much, a chasing in the wall can be made sufficiently deep to receive about half the pipe. Stoneware pipes are sometimes also used for soil-pipes, but are not to be recommended inside houses, at any rate on account of the numerous joints that have to be made. Occasionally, where work is "scamped," soil-pipes are even made of zinc, and in the Parkes Museum is a specimen of a D-trap made of very thin lead, with a zinc soil pipe attached. The latter has been eaten through by the foul air, as might be expected. Foul air is also capable of perforating lead soil-pipes, especially if they are not ventilated, and in the same Museum is a specimen of a lead soil pipe, which was taken from under the floor of a bedroom, where it had very little fall, and which is perfectly riddled with holes, eaten through the solid lead by the foul air which accumulated in the pipe. A still more remarkable specimen, which I had removed from one of the best closets in a country house, is also in that Museum; in this the D trap, soil-pipe, safe with its waste pipe and the waste pipe of a sink (ending in the D trap) are all made of zinc, the only part made of lead being the waste pipe of the cistern which supplied the *W.C. and the sink*, and which also ends in the D trap; the zinc soil-pipe was not ventilated and ended in an iron one which was connected by an un-ventilated pipe drain with a cesspool; large holes caused by the foul air are seen in the top of the D trap; repeated outbreaks of sore throat were produced in this instance.

In order to ventilate a soil-pipe, it is not sufficient merely to carry a small pipe, such as an inch or even a 2-inch pipe, from the upper part of it to the top of the house, but the 4-inch soil-pipe itself should be continued (full bore) to the top of the house, and should as a rule, project above the ridge of the roof. It may be covered simply with a perforated conical cap, not fixed on to the top of the soil-pipe, but fixed so as to stand a little above it, and not to obstruct the flow of air out of it, or two or three copper wires may be fixed across the top, so as to prevent leaves from getting into it. Cowls of any kind are quite unnecessary at any rate in the great majority of instances. Where an air inlet is made into the house sewer, the soil-pipe should be carried into the latter by means of a bend—no trap of any kind being placed at the foot of it, but where this is not the case, or where it is not proposed to ventilate the house sewer by means of the soil-pipe, or where the soil-pipe cannot be carried above the roof, it is advisable to place a disconnecting trap of some kind at the foot of the soil-pipe outside the house. In any case it is necessary that provision should be made for a free passage of air through the soil-pipe. When the vertical soil-pipe is at some distance from one or more closets, so that the branch pipes from the closets to the soil-pipes are, perhaps, a few feet long, it is a good plan, and sometimes necessary, to carry small ventilating pipes from below the trap of the closet, and connect them to a pipe outside the house, which should be continued up above the roof. This will prevent an accumulation of foul air in the branch pipes and will also prevent the water passing down the main soil-pipe from drawing the water out of the traps of closets beneath. It has even been proposed by Mr. Norman Shaw to disconnect the branches of the soil-pipes of the closets from the main soil-pipe outside the house, by making them discharge into open heads, something like the heads of the rain-water pipes ; and Dr. Heron has devised a plan in which part of the branch pipe is moveable, and so arranged that it is only connected with the main soil-pipe when the lid of the closet is open, but is removed from it by the closing of the lid ; while Mr. Buchan has proposed that the branch pipe should be a channel pipe, freely open to the air along the top.

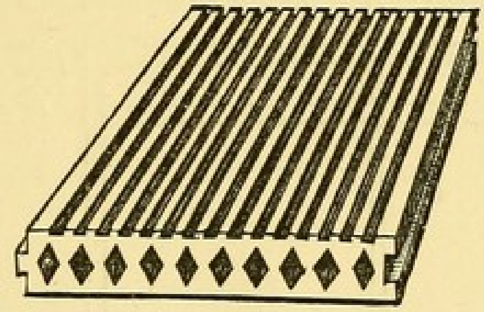
Water-closets should, whenever it is possible, be separated from the house by a ventilating lobby, or, at any rate, there should be two doors with special means of ventilation for the space between them, and this leads me to speak of Mr. Saxon Snell's invention, in which by means of an arrangement called "The Duplex Lid," the closet apparatus is placed, by the closing of the lid, in a shaft which is carried up above the roof of the house. The water supply is also connected with the lid, so that the lid has to be closed in order to flush the closet.

We now come to sinks and baths.

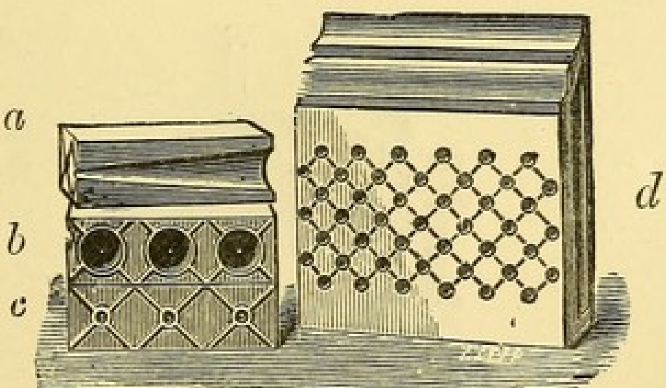
Of sinks there are various kinds. Sometimes sinks called "slop sinks" are provided to get rid of the dirty water, although where wash-out or hopper closets are used the slops may be thrown down them. The waste-pipes from slop sinks should be provided with syphon traps, and are as a rule, connected with the soil-pipes. They are, in fact, looked upon in much the same light as water-closets. The other upstairs sinks, as "house-maid's sinks," and the small sinks under taps, known as draw-off sinks, must not be connected with the soil-pipe or water closet apparatus. Their waste-pipes should always be provided with syphon traps immediately under the sinks, in order to prevent air coming into the house through these pipes, as it is rendered foul by so doing, but at the other end these waste pipes should always be disconnected from the house sewer, discharging into a pipe with an open head like a rain-water pipe, or over a gully in the area. Scullery sinks should always be disconnected from the sewer, but there is a difference of opinion as to whether or not this should be by means of a trap large enough to collect the fat from the greasy water thrown down there. If such a trap is used, it must contain sufficient amount of cold water to cool at once the hot water from the sink that is thrown into it. But in any case, the pipe from the sink should pass under an open grating before entering such trap. The waste-pipes from baths should be invariably disconnected from the house sewer in the same way as those from sinks. The waste-pipes of baths should be large, say two inches in diameter, not only so that they may be quickly emptied, but that the large body of water being discharged suddenly may be made to flush the house sewer. In large houses, where there are laundries, this is a still more important matter. A bath should have a lead "safe" tray placed under it, the waste pipe of which must go straight through the wall of the house, and end in the open air. The disconnecting traps used in the areas for the waste-pipes of sinks and baths may be either the ordinary syphon gully-trap with a galvanised iron grating (the waste pipe being made to discharge either over the grating, or preferably, as a rule, through holes in the side of the trap below the grating, but above the water in the syphon), or Mansergh's trap may be used, especially for scullery sinks, or sinks on the basement floor.

To conclude. The principles that guide us in carrying out sanitary works are simple enough, but sufficient has been said in these lectures to convince everyone that it is only by the minutest attention to details that we can hope to guard ourselves against the dangers that surround us, especially in the contrivances for the removal of refuse matters.

ILLUSTRATIONS.

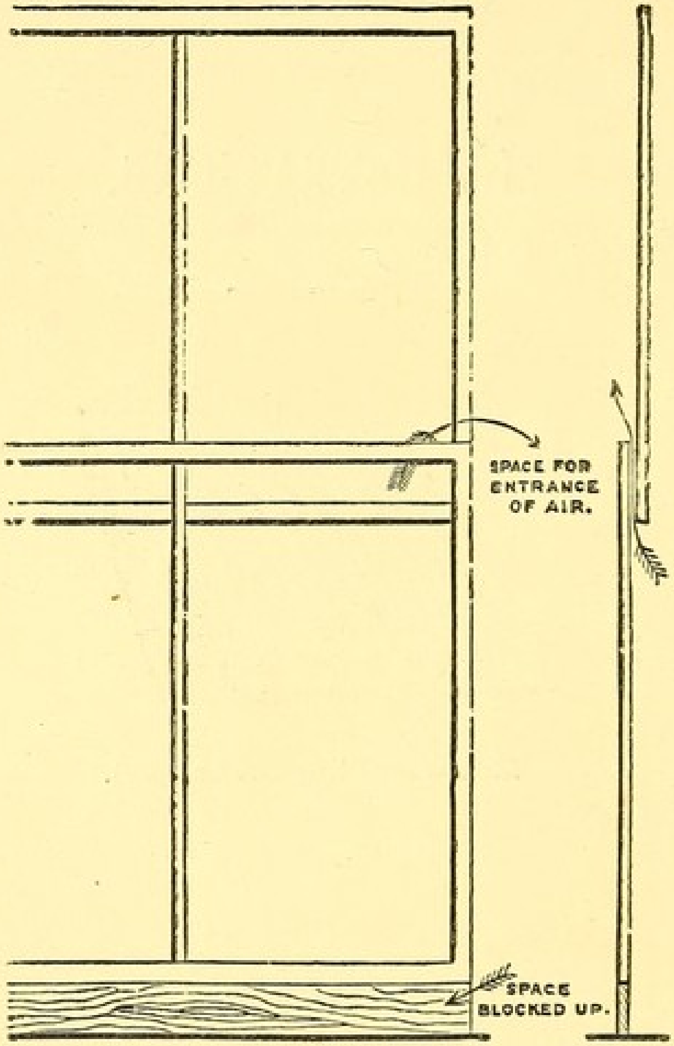


Stoneware Damp course, (p. 7).

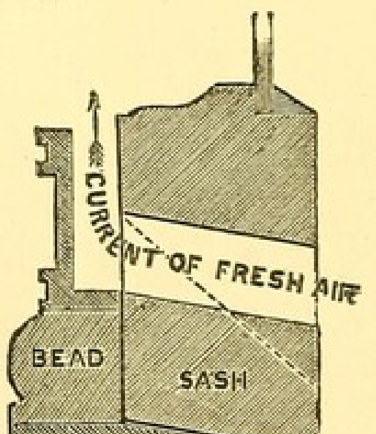


Conical Ventilators.

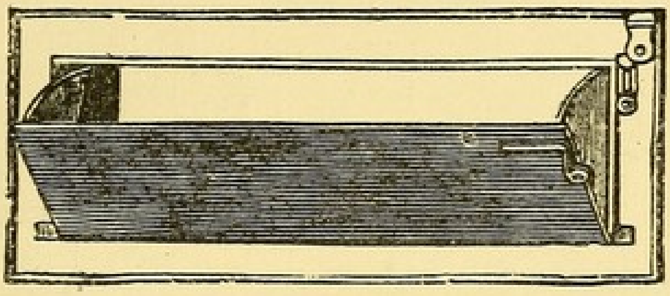
(*a.*) Section of perforated brick. (*b.*) Inner surface. (*c.*) Outer surface.
(*d.*) Perforated skirting board, (p. 10).



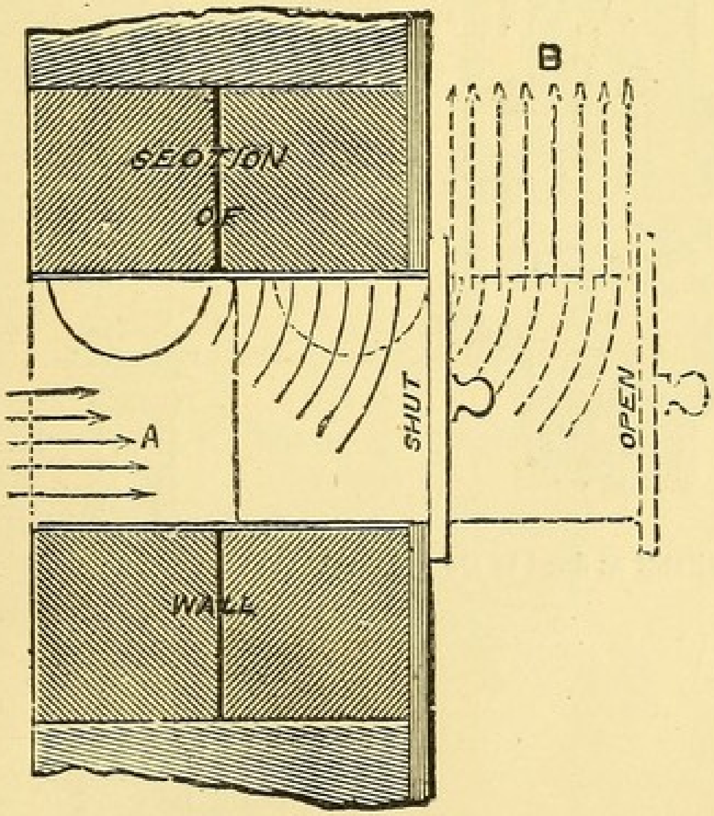
Plan of "Costless Ventilation," (p. 20).



Currall Ventilator (as fixed to Window), (p. 21).

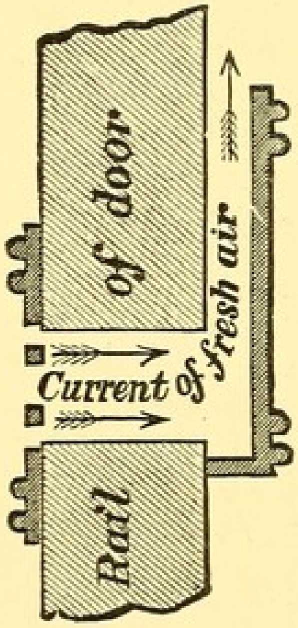


Sherringham Valve, (p. 24).

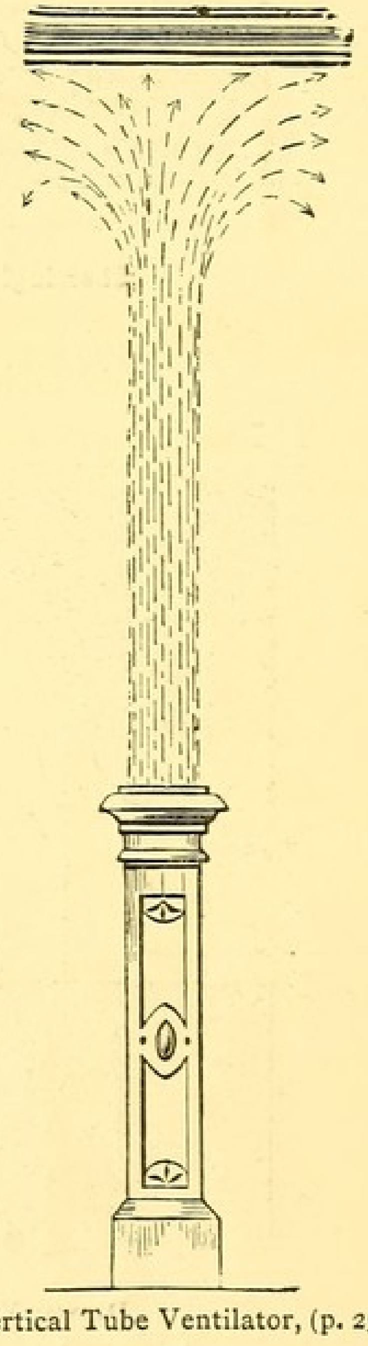


Drawer Ventilator, (p. 25).

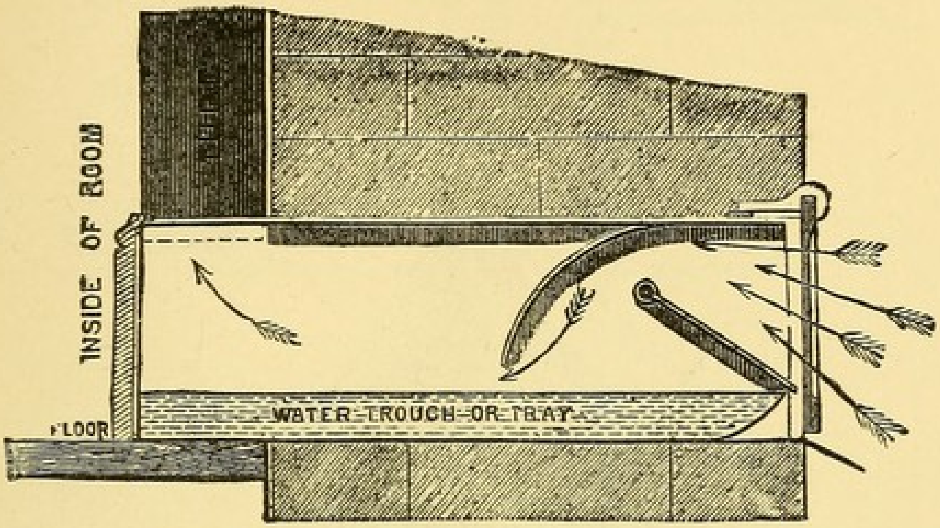
A. Direction of air entering ventilator.
B. Direction of air entering room.



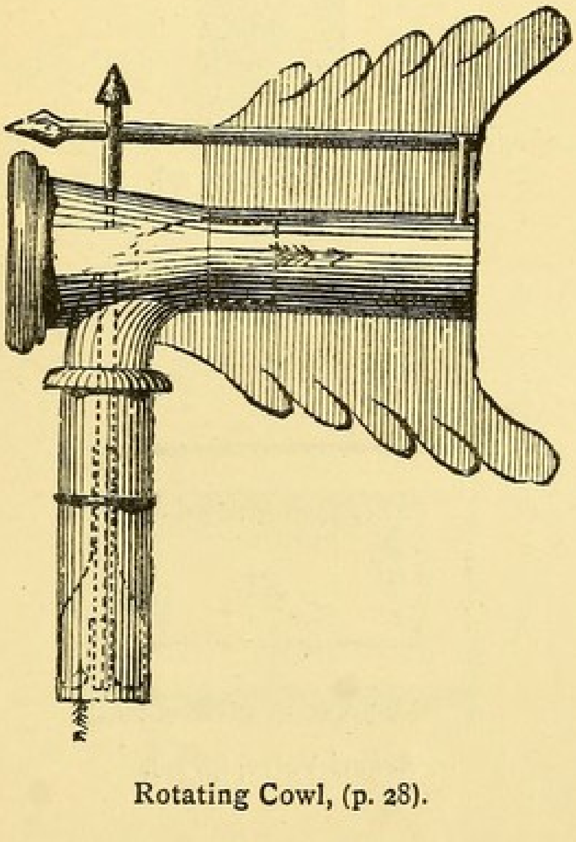
Currall Ventilator as fixed to Door, (p. 25).



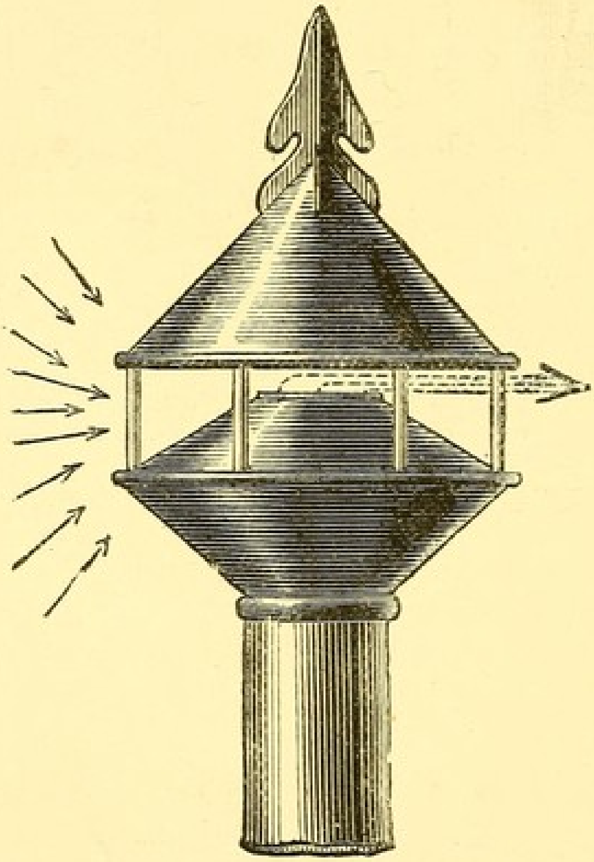
Vertical Tube Ventilator, (p. 25).



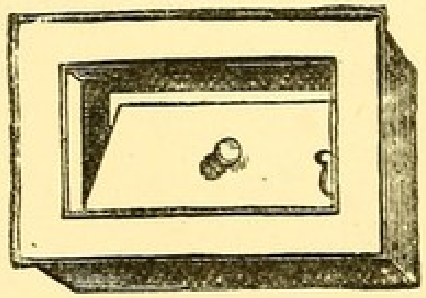
Water Tray for Vertical Tube Ventilator, (p. 26).



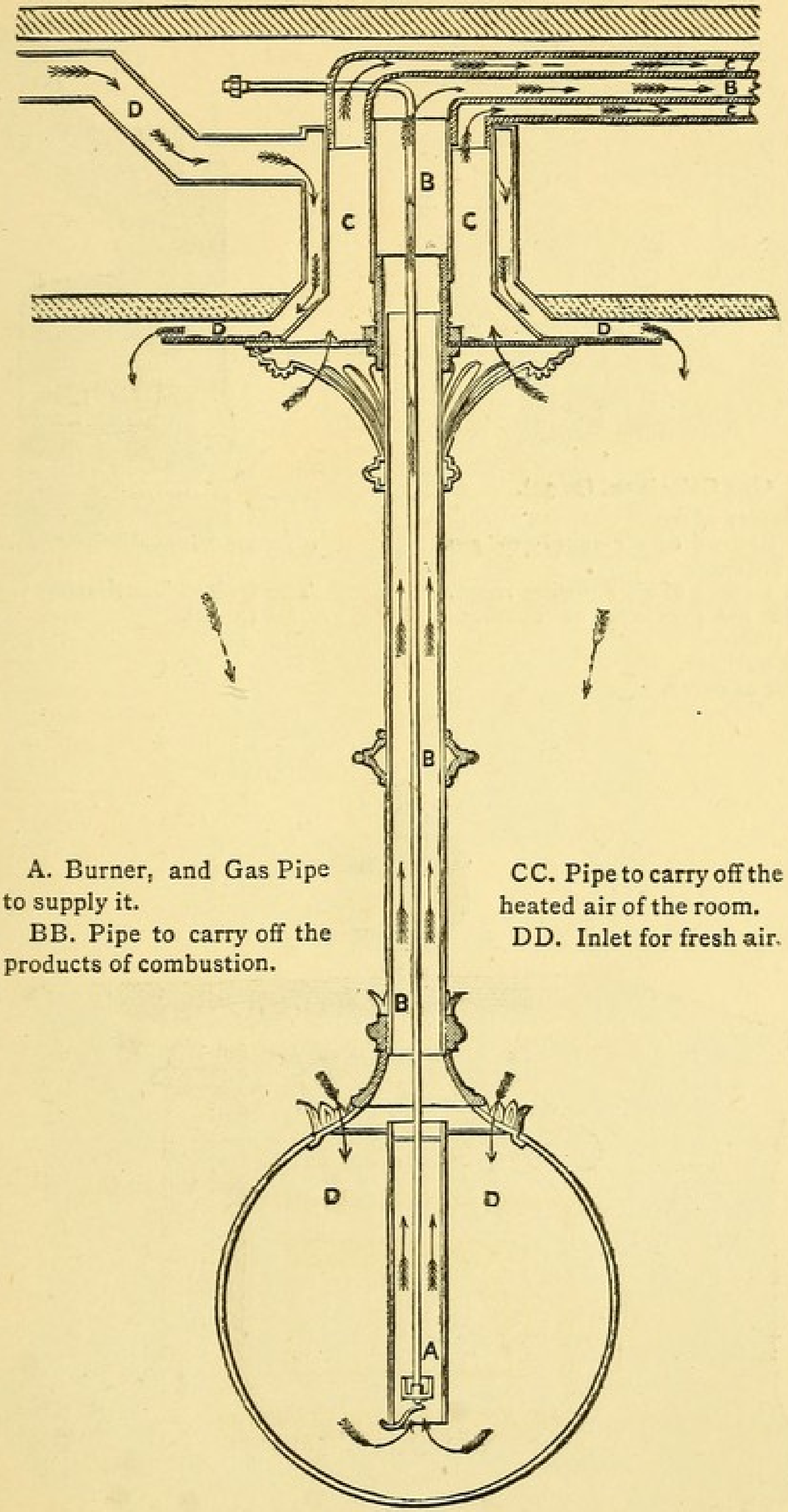
Rotating Cowl, (p. 28).



Fixed Cowl, (p. 27).



Arnott Valve, (p. 28).



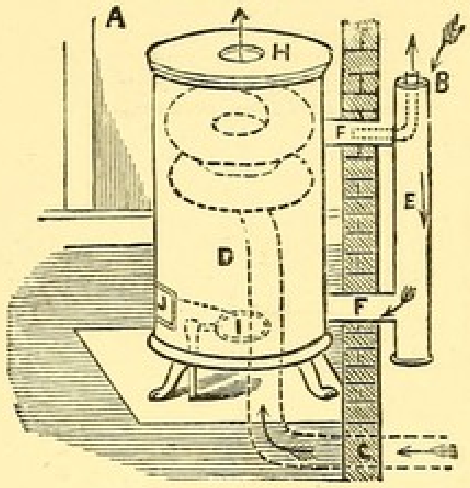
A. Burner, and Gas Pipe to supply it.

BB. Pipe to carry off the products of combustion.

CC. Pipe to carry off the heated air of the room.

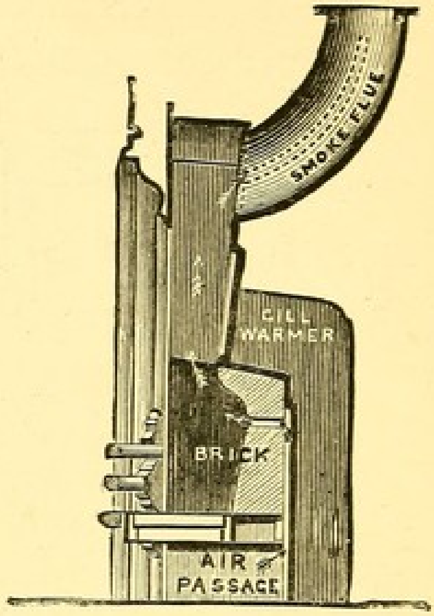
DD. Inlet for fresh air.

Ventilating Globe-Light, (p. 32).

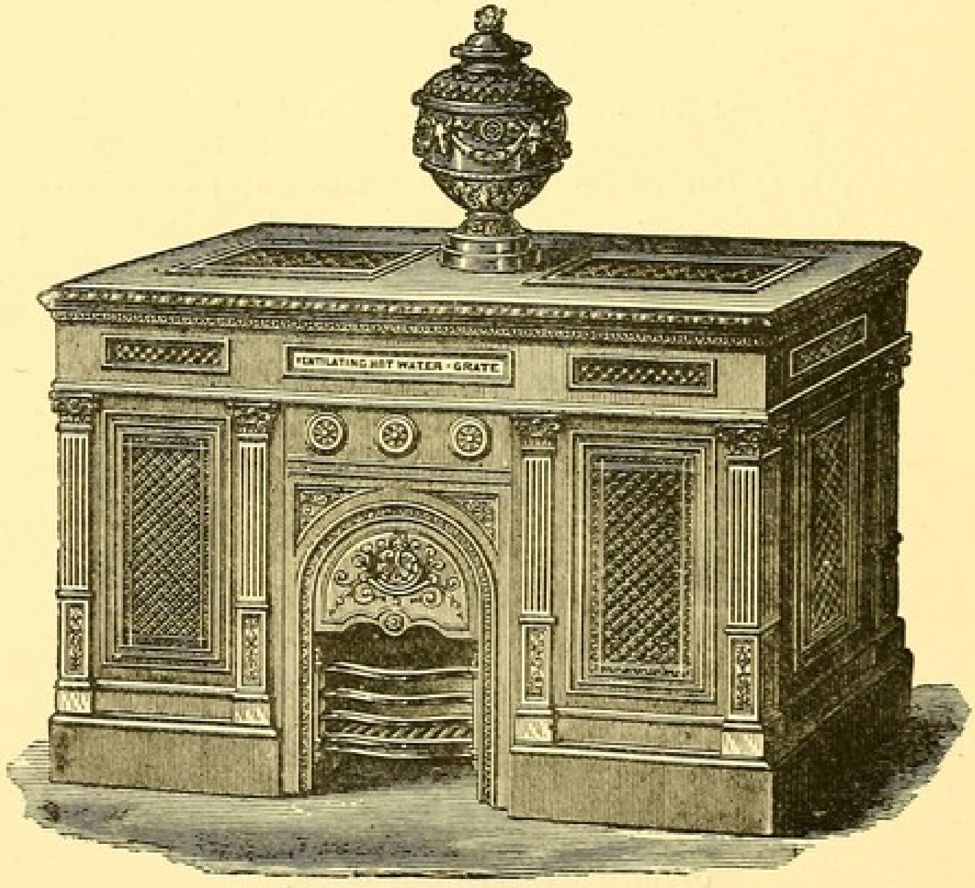


Gas Calorigen, (p. 33).

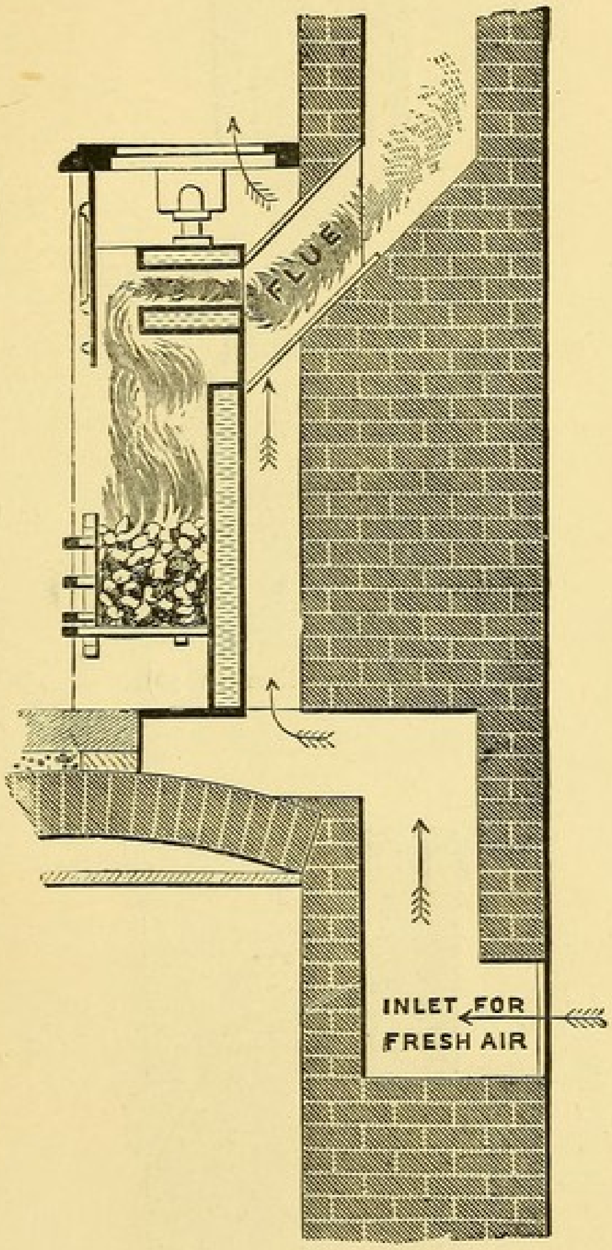
A. Interior of room
BEF. Course of air-supply to gas burners.
CDH. Course of air entering room.
F. Exit for products of combustion.
I. Gas burners.
J. Door of stove.



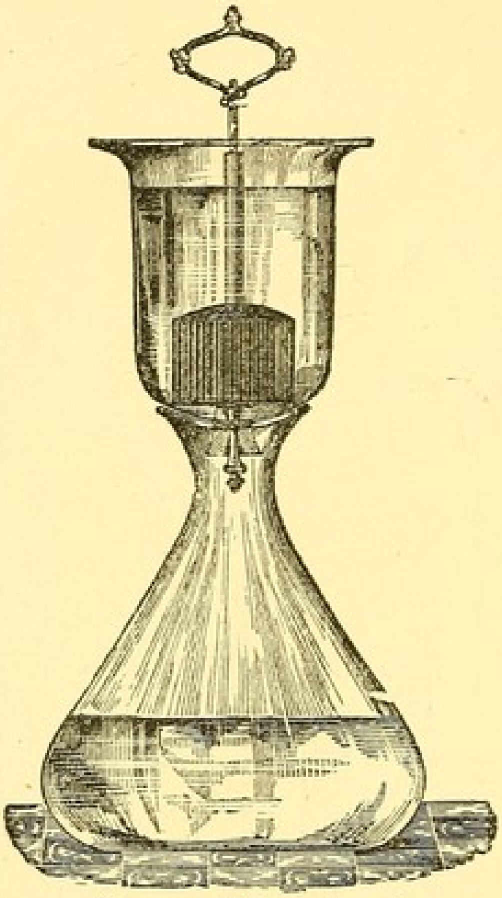
The Galton Ventilating Grate, (p. 32).



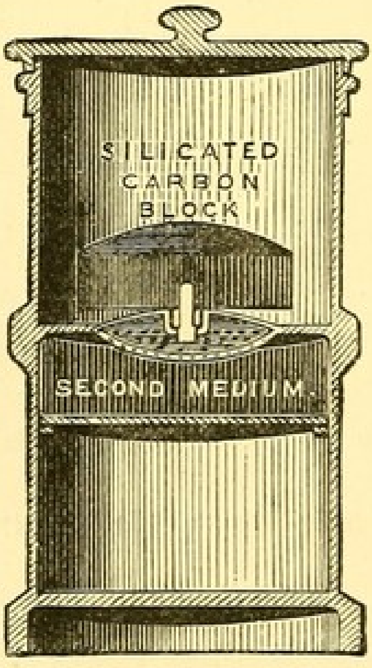
Thermhydric Grate, (p. 34).



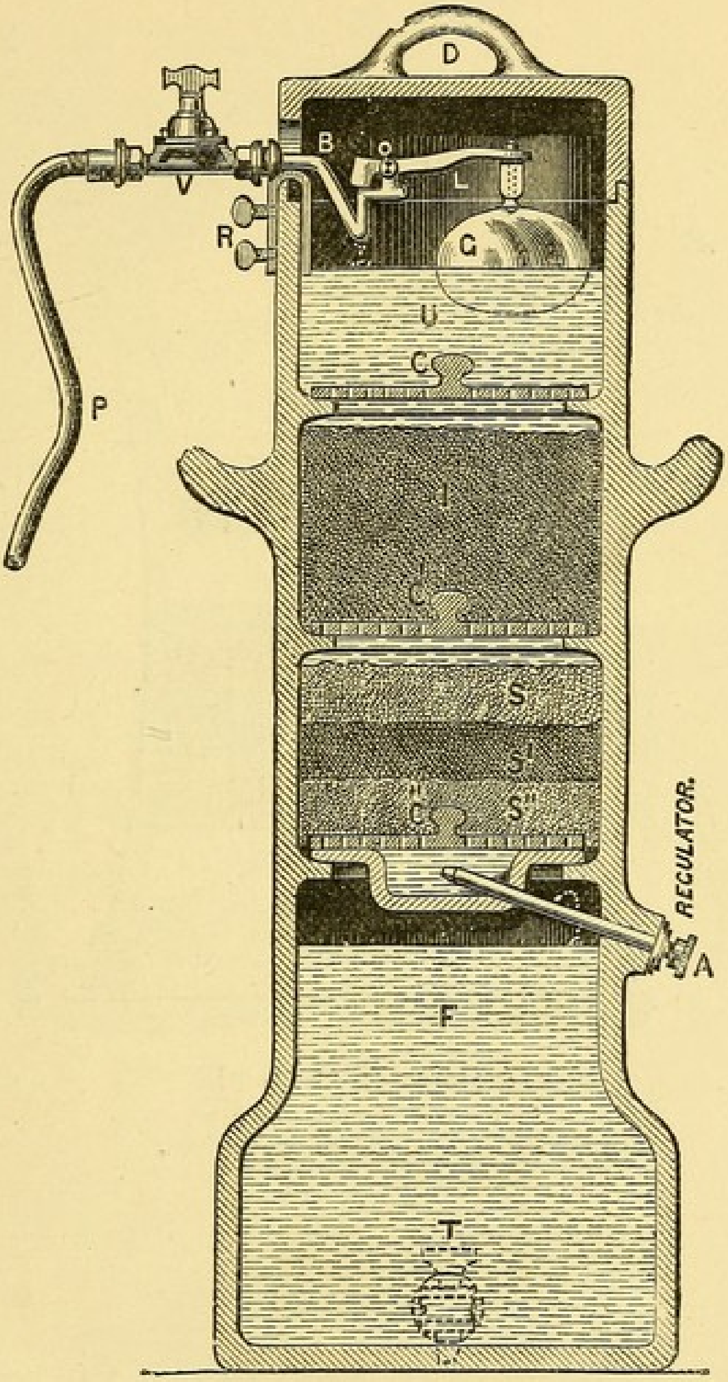
Thermhydric Grate. (Section), (p. 34).



Decanter Filter, (p. 50).

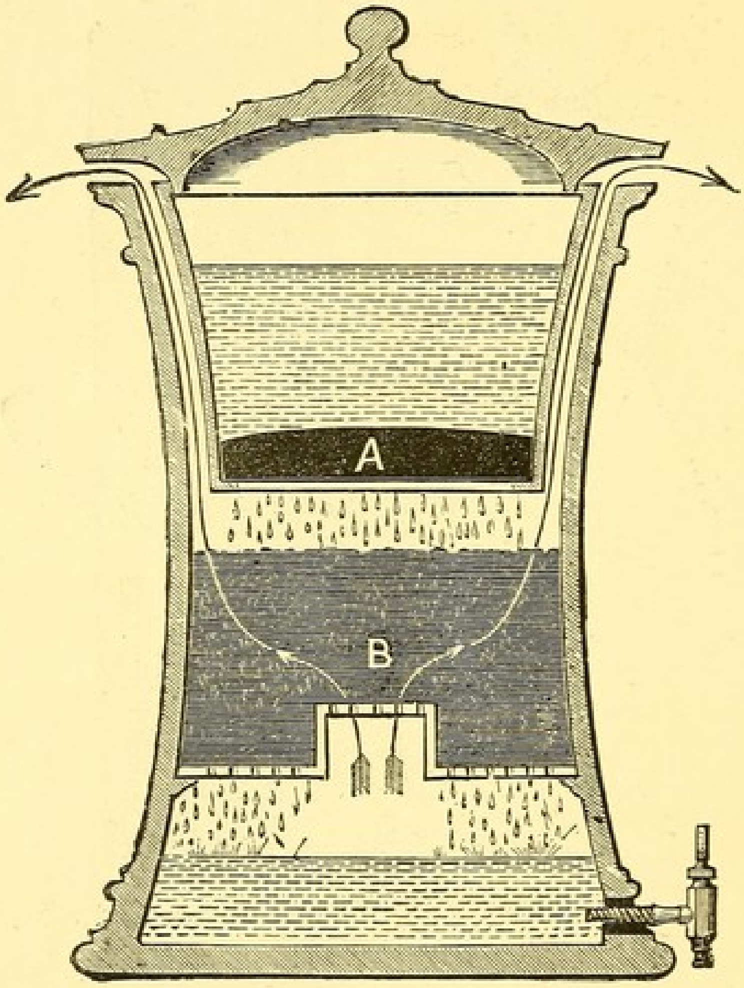


Silicated Carbon Filter, (p. 50).



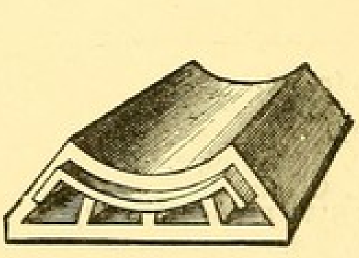
Spongy Iron Filter, (p. 51).

A. Access to regulator.
B. Water supply tube entering filter.
CC'C" Floors of filter chambers.
D. Handle of cover.
F. Filtered water chamber.
G. Floating ball.
I. Spongy Iron.
L. Lever worked by floating ball.
O. Ball valve.
P. Supply pipe.
R. Clamp.
S S'S" Prepared sand, &c.
T. Tap.
U. Unfiltered water.
V. Screw down stop-cock.

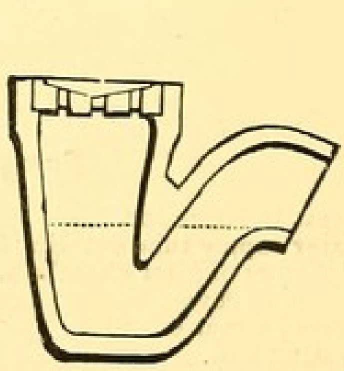


Aerating Filter, (p. 51).

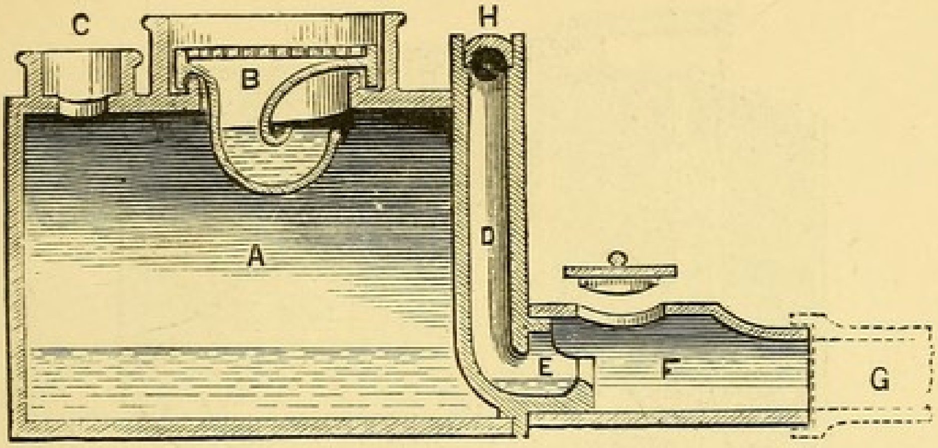
A. First Filtering medium.
B. Second Filtering medium.



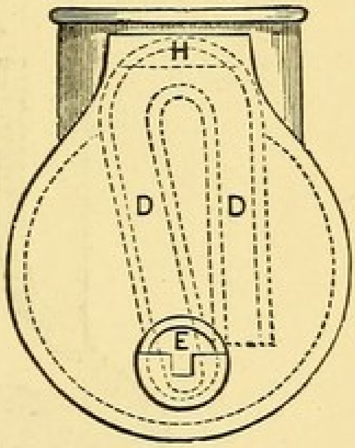
Invert Block, (p. 66).



Syphon Gully, (p. 75).

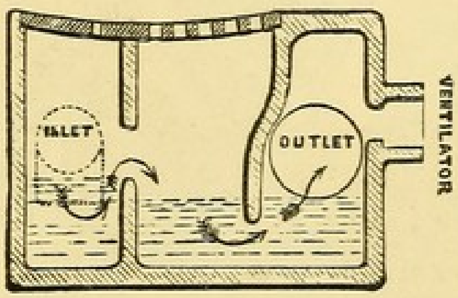


Field's Flush Tank, (p. 65).

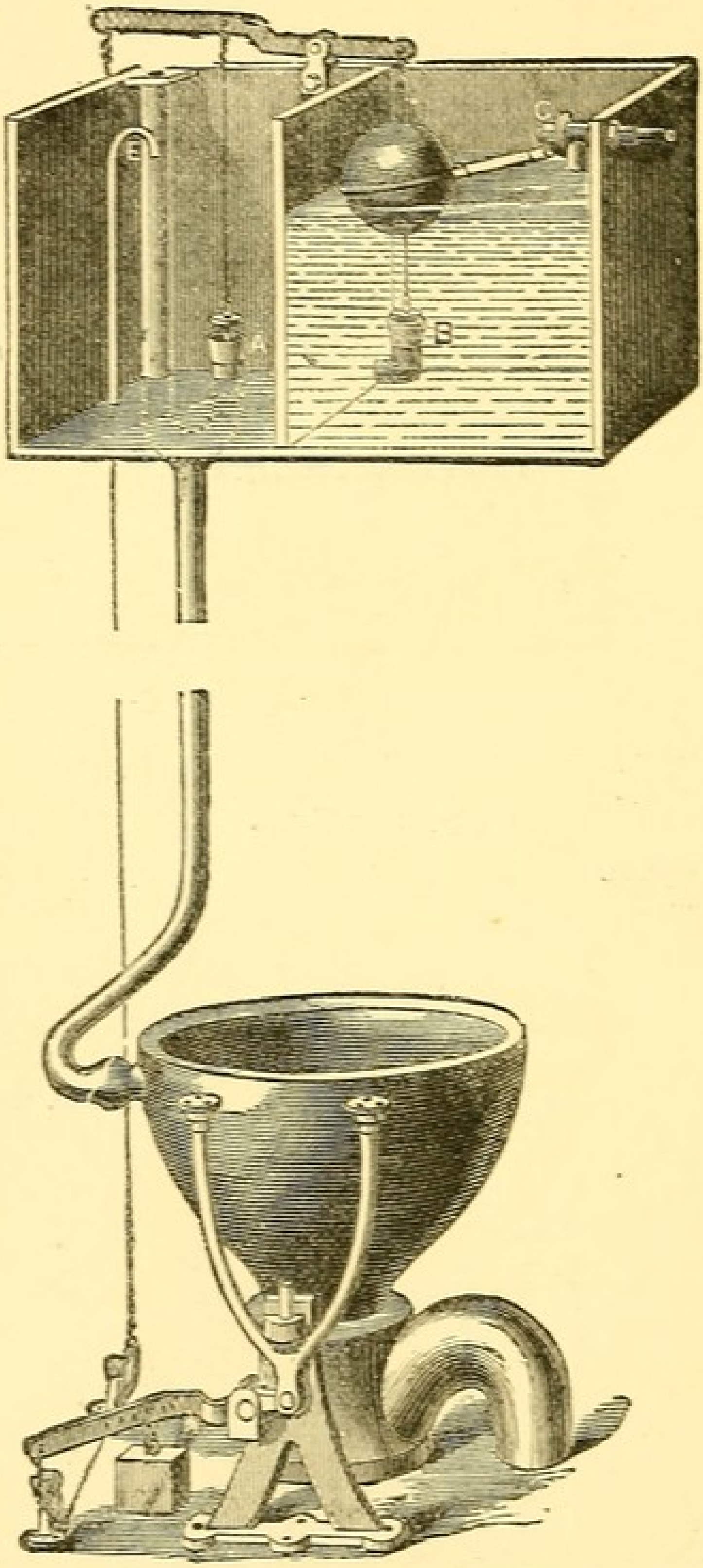


A. Interior of tank.
B. Surface grating.
C. Connection for rain water pipe or ventilator.
DD. Syphon.
E. Outlet of syphon.
F. Connection.
G. Drain.

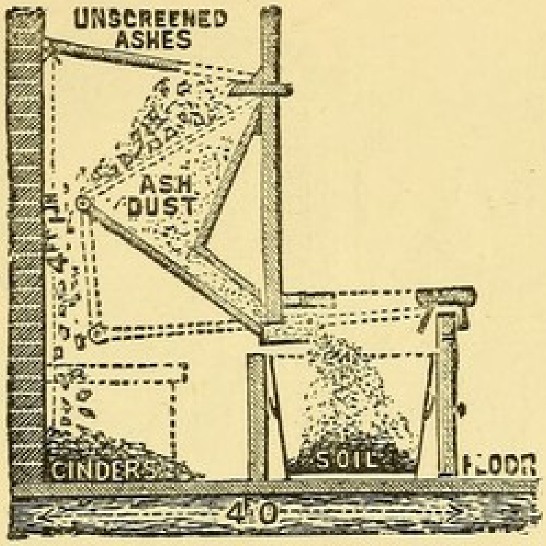
End of ditto. Inside view.



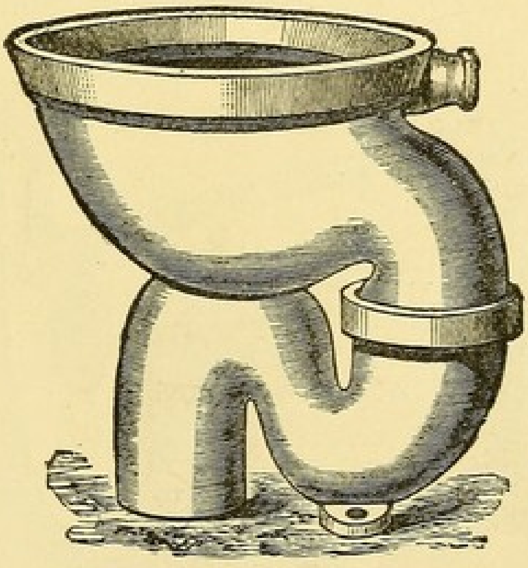
Mansergh Trap, (p. 76).

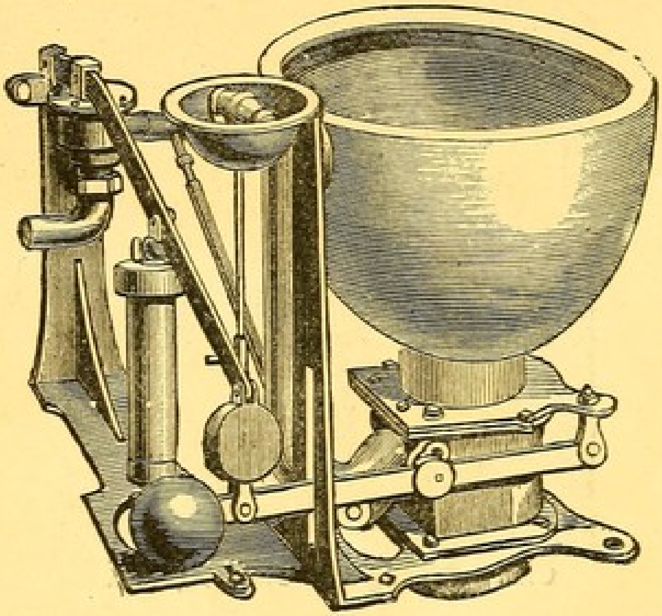


Hopper Water Closet with Water Waste-preventing Cistern, (p. 79).
A. Valve on service pipe.
B. Valve on communication pipe.
C. Ball valve.

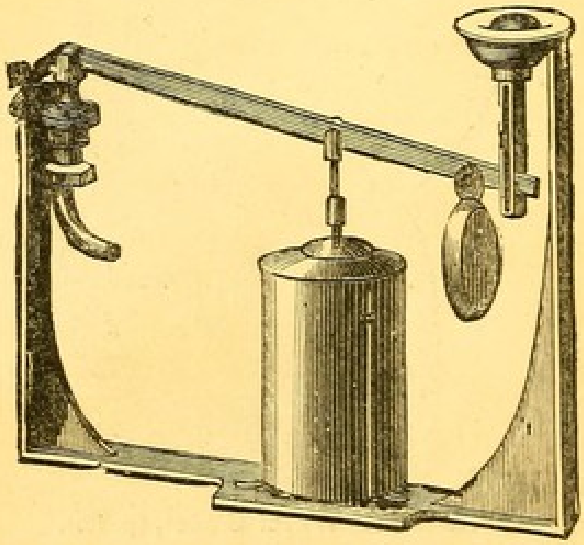


Cinder Sifting Ash Closet, (p. 60).


" Wash-out" Water Closet, (p. 80).



Valve Water Closet, (p. 84).



Water Closet Supply Valve with Bellows Regulator, (p. 90).