SANITARY SCIENCE:

AS APPLIED TO

THE HEALTHY CONSTRUCTION OF HOUSES IN TOWN AND COUNTRY.

BY

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"Sanitary instruction is even more essential than sanitary legislation."

—Lord Derby at Liverpool, 1872.

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PREFACE.

Those familiar with the literature of Sanitary Science will know, that it would be an easy matter to prepare a work devoted to one only of its many branches; and of much greater extent than the present, which occupies itself with the discussion of the whole of them. Much matter, therefore, must have obviously been omitted, which might have been given. But although this be not given, it is only right to state that the work is therefore not necessarily incomplete. On the contrary, the author has used his best endeavours, with what success its pages alone must testify, to make it as complete as far as its scheme extends. That scheme, it is scarcely necessary to say, does not include a history of the phases through which Sanitary Science has passed, and is now passing; nor an elaborate dissertation on the influence on the social and moral well-being of the community which it exerts, and is likely in a still more marked and beneficial manner further to exert, when the principles of the science are more thoroughly diffused, and the practice based upon these is more widely extended. The space, therefore, which might have been devoted on another plan of the work to matter of this kind, although it might, perhaps, have rendered its pages more popularly interesting, has been left for the discussion of subjects which the author trusts will make them more practically useful.

The remarks on the various departments treated of, have been made as practical as possible, so as to be applicable to the ordinary circumstances of town and country districts and houses. In offering these remarks, the author has been guided, not only by a fairly intimate acquaintance with what has been made public during the last fifteen or twenty years on Sanitary Science, but by such experience as he has derived from a practical professional working out of the details, of more than one of its branches. His views on some of their points are no doubt peculiar, and he is well aware that they are by no means popular, or rather, he should say, not in accordance with the views which are popularly held in connection with them. He has, however, come to his conclusions on what he considers to be a sound basis of facts and figures. To some of the points involved, he has in the course of the last few years, devoted papers more or less exhaustive in the pages of the leading Agricultural Journals—as the "Journal of Agriculture,"—"The Mark Lane Express,"—"The Farmer,"—"The Agricultural Gazette," and "The Journal of the Bath and West of England Agricultural Society." Some of these papers he has drawn upon, to a small extent, in the following pages.

Although the Author has endeavoured to make his remarks as practical as possible, still the scheme of the work does not admit of the technical details connected with the various branches of the science being described. To those, therefore, of his readers who may be desirous to become acquainted with these details, he may be permitted to refer to his larger works—"Practical Ventilation," and "Dwellings for the Working Classes;" "The New Guide to Carpentry, General Framing, and Joinery," and "Masonry, Bricklaying, and Plastering;" and for a full exposition of his views on the agricultural aspect of the Town Sewage Question, to the volume forming part of Weales' Rudimentary Series, entitled "The Utilisation of Town Sewage: Irrigation and Reclamation of Land."

While fully aware of the shortcomings of the work, the Author nevertheless trusts that it will in some measure tend to supply the want which undoubtedly exists for a plain, practical treatise on a subject of vast importance to the community; a want which the Publishers felt should be supplied when they asked him to prepare its pages. To them his thanks are due for the opportunity they have now afforded him of doing what little he can, to aid in the diffusion of information, on the principles and practice of a science which is so well calculated to minister to the comfort and health, and to promote the social advancement, of the people.

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PRINCIPLES AND PRACTICE
OF
SANITARY SCIENCE.

CHAPTER I.

GENERAL CONSIDERATIONS AFFECTING THE SANITARY CONDITION OF TOWN AND COUNTRY DISTRICTS.

From the clinging to life and the desire we all have to lengthen out its term, it would be natural to suppose, that even from the earliest times of civilisation marked prominence would have been given to the art of so arranging and constructing our dwellings as to secure to the fullest possible extent the daily health of their inmates; and that for healthy construction we would willingly have sacrificed even much of our comfort and convenience; certainly that, before we thought of adding to our houses the luxuries of art which wealth and ease of circumstance bestow, we should have taken every means to secure an ample supply of what all know beyond a doubt to be the necessaries of existence, as light, pure air, and water, without a due supply of which, life languishes, and, under their total deprivation, diseases break out, and death inevitably ensues. But this, which we may call the natural inference which would be drawn from the circumstances attendant upon our physical existence, has not been, in the past history of our people—nor, strange to say, even in the midst of this our boasted nineteenth century civilisation, is it now—met with. For examples of what may be called national sanitary practice we have to go back to remoter times, and we find amongst the Jews and the Romans, in the old, and amongst certain nations in the new world, that their times were as marked by the attention they paid to the laws of health, as ours have been for a long period, and are to a large extent even now, distinguished by neglect and indifference. For long in the history of our nation, the "art of sanitation," as it has been called, was a lost one, not merely lost in the darkness of the middle ages, when plagues decimated the population of our cities, but lost even in times which approach closely to those we now live in. The present generation is indeed only witnessing its revival; and we are even now, it is to be feared, suffering from the mistakes which but too often accompany a hasty attempt to carry into practice laws which have been so long and so completely neglected,—for the attempt has been hasty, and, like all hastily-done things, not too well considered. A generation has scarcely passed away since very marked prominence was given for the first time in our social history, by a series of investigations, prompted, in the first instance, chiefly by individual philanthropy, but, it is right to add, most zealously taken up by Government bodies and Scientific Societies, to the whole bearing of what was called the "Sanitary Condition of our Towns and Cities." When the result of these investigations was made public in the shape of elaborate Government reports, and papers, read before our various Scientific Societies, it was startling enough in its effects upon the public mind. For the first time the public were made generally aware of the condition of matters existing in their very midst, of a character as dangerous to their health and their social welfare as it was scandalous to their civilisation. The statements made as to the condition of matters in the streets and alleys and courts of those parts of the towns inhabited by what are called the "poorer" or "labouring" classes, were, in their plain, bold truthfulness of detail, most appalling, and were calculated to give rise to serious thought and vigorous action in order to remedy them. The result was, that for many years much was done to remedy these evils; but they were found in practice to be so extensive, and to present such a many-sided aspect, any one of which was most difficult to legislate for, that all that was done was as nothing to what had to be done. Nor must it be concealed, that after the first shock, so to call it, which the public mind sustained by learning the evils existing in our towns and cities, and after the first eager anxiety to do something to get rid of them, an apathy and an indifference gradually succeeded it, and things were to a large extent again left to go on very much in the old way. Indeed, on this great question, it may be said that our efforts to do better in connection with it have been at the best of a somewhat spasmodic character. It is, we fear, too much the truth, that it was only at times when the "pestilence" threatened, or fever stalked through the land, that men began heartily to move in the matter of sanitary reform.

Then the waters of apathy were stirred, and great exertions made to rid our towns of the plague that stirreth at night and the "pestilence that walketh by noon-day." Then committees sat in solemn conclave, and commissioners of police headed armies of whitewashers, forgetful all of the fact that hiding dirt was not getting rid of it, that scotching the snake was not killing it.

Then Boards of Health gave sage counsel to the poor people to wash well their houses and keep their persons clean, unmindful of the fact that in many cases no water glistened near their dwellings, and that no drains existed to sweep the foul proceeds off. Work done in this way, and advice given to the poor in this style, is too apt to remind us of the folly of him who holds out a rope to a drowning man with one hand, and with the other gives him a lusty knock on the head, taking away all capability of using the means of safety; it is like telling a man who begs of you to go and buy himself a new suit of clothes that he might beg at least respectably. When we think of some of the schemes of sanitary committees, and the "recommendations of boards of health" or mayors of towns during times of pestilence, we are reminded of Burke's celebrated description of the Chatham ministry as peculiarly apposite—"An administration so checkered and speckled—a piece of joinering so crossly indented and whimsically dovetailed; a cabinet so variously inlaid; such a piece of diversified mosaic, such a tessalated pavement without cement, here a bit of black stone, and there a bit of white . . . that it was indeed a very curious show, but utterly unsafe to touch and unsound to stand upon." And although matters are now much altered for the better, and although a real desire exists on the part of town and city corporations to do their part in getting rid of the evils arising from a want of sanitary regulations; it is, nevertheless, too true that matters are still so bad, that even in many districts it is the opinion of many that they could not be worse. And although much has been done to rouse the public from their apathy upon the subject, still their is grave reason to believe that a new generation since the period we have above alluded to has arisen, who have got indifferent to the subject; to its influence upon the health —social and moral—of the community, who overlook and wilfully overlook the evils surrounding them, or who will not believe that they exist at all, or if existing they are not so bad as they are said to be. To such, a few facts and general consideration connected with the subject may be of use.

Could one with somewhat of Asmodean power, not unroof the houses, but skim over the streets of any of our large cities, what strange contrasts would he behold! Here, wide, well swept streets, lined on either side with large, well-built mansions; or shops, filled with everything that can tempt the luxurious or refined, or minister to the utilities of life; and but a stone's throw off, a narrow, noisome street, heaped up here and there with garbage foul, offensive to sight and smell. Stately warehouses containing wealth that would have ransomed kings long ago, overlooking hovels sheltering, not half covering, the wretchedness of the poorest of the poor; hospitals looking out upon the lazar houses from which come the occupants of their wards; churches crushing in where the sound of praise and the song to heaven mingles with fierce curses of men and the shrieks of women and children; the windows of a Bible warehouse in a broad street looking out upon a brothel; a police-office fronting a "flash house,"—these and a hundred other contrasts as strange and striking, would make up the mingled mass which that city is. Which of our cities can be said to be without its plague spots? Which of our towns without its death shadows? Walk the streets of London, and if your guide is a vain man, prompt only to show you in his vanity the evidence of the wealth and power of the world's capital, he will lead you through stately squares and crescents, but he will pass by the courts and alleys, and the narrow streets, of the condition of which, the following is but too true a description:

"The streets, courts, alleys, and houses, in which fever first breaks out, and in which it becomes prevalent and fatal, are invariably those in the immediate neighbourhood of uncovered sewers. Mark the dreary list—stagnant ditches and ponds, gutters full of putrifying matter, nightmen's yards and privies, the soil of which lies openly exposed, and which is seldom or never removed. It is not possible for language to convey an adequate conception of the poisonous condition in which large portions of these districts remain winter and summer, in dry and rainy weather, from the masses of putrifying matter which are allowed to accumulate." Or another picture: "A labyrinth of squalid rooms above, littered with dirty beds, and smelling inexpressibly foul." Or another: "The type of hundreds of others easily met with in our cities, of a room, in one corner of which was a little heap of dirty straw, on which nestled, intangled in strange confusion, some children—it was impossible to tell how many." Or another room: "In which the walls were rotten and full of cracks, matted with layers of mouldy paper, swarming with vermin; gaping holes in the floor, filled up by great stones, and moonlight visible through the fissures in the walls." Or still another: "Dirty as a pig-stye, with a heap, swept in a corner, of ashes, filth, herring bones, and muck miscellaneous." Further, let the reader conceive of the internal condition of houses to which a stair leads, in which, "from bottom to top, were heaps of rubbish and oozy filth, from which passages branched out like the gallery in a coal pit winding in and out in seemingly endless coils among the rooms, separated by rotten vermin-haunted partitions." What with the sights and sounds of vice and misery around him, the positive danger arising, no less from the tottering staircases and bulging-out walls, supported chiefly by the blackened beams stretching across and half obscuring the glimpse of sky seen overhead, than from the swearing, haggard men, and the scolding, flaunting women, the attendant demons of the place, it takes a man of strong nerve, and still stronger sympathy with the wrongs and sufferings of the poor, to enter coolly such wretched quarters. If such a condition of matters characterises certain quarters of the richest and most advanced of our cities, the reader may have some faint notion of the work that is yet to be done by sanitary reform.

But it must not be supposed that sanitary evils and the deplorable state of matters arising from them are to be met with only in our towns and cities or populous villages. They are unfortunately found to exist in rural districts, in which, according to popular fancy and story only peace and comfort dwell. Here are a few cases chosen out of a long list descriptive of the cottages of the poor labourers met with even to-day in too many of our rural districts :

The cottages are mere hovels of mud or of "wattle and daub," or of rubble stone set in mud, or of rude timber frames filled in with mud, or with brick, or with stone, or with other material. The timber is rotten ; the mud, bricks, and stones are damp in wet weather, and dusty in dry weather. Look at the site—probably a hole—not unfrequently a swamp several feet below the adjoining road, the slope being towards the door. If on an elevation, the ground is undrained, rugged, abrupt, uneven, and neglected. Many of these hovels are only one storey in height ; the side walls are very low—from 3 to 6 feet up to the square ; few are vertical, and some are supported by buttresses or by props. Many are half buried against a hill side, or against a bank which is wet. Then the roof—this is of thatch, of heather, or of straw, or is formed of turf, of sods, of shingle, of tile, or of slate. If of thatch, the material is rotten with age, and green with fungoid vegetation ; if of shingle, the timber is decayed ; if of slates, they are broken and in holes. Door and windows match the structure, and the floor is of native mud, the space enclosed being common to bipeds and to quadrupeds alike. The floor is not only dirty, but the walls, furniture, and roof are the colour of grimy dirt. Amongst the rafters, spiders and other insects abound. Outside, animal refuse is stored in some hollow where liquid permanently rests, so as to keep up evaporation and an evolution of gasses highly injurious to human life; and if this refuse does not actually surround the hovel, it is frequently so situated that the prevailing winds shall drive the gases of decomposition into and through the habitation. The arrangements for disease, misery, and premature death are ample, adequate, and complete. The hovel is crowded by males and females of all ages, without means of separation, so that the arrangements for sin and misery are also complete.

To this general picture may be added sketches from particular districts, as the following: In one district, the cottages, or rather huts—to call them by their right name—" are constructed of a rough frame-work of timber, with heather or gorse interwoven, about two or three feet in thickness. The walls, if they may be so called, are not generally higher than about six feet; the roof thatched, with poles laid crosswise, and bound, to prevent its being torn up by the wind. In addition to this, ropes constructed of twigs are suspended, and attached to large stones, to give additional security." In another district near the above, the cottages are sometimes built of stone, sometimes laid in regular fashion. " Others are of rough stones of all shapes, something like a stone wall laid without mortar, and afterwards plastered in a rough way; others of river or rounded stones. The height of wall is not more than six feet; thatched roof; chimney constructed of a light frame-work of sticks, with turf laid against it. There are never more than two rooms, no ceiling, very often no fire-grate; but when there is, it is of the rudest description. The floors are generally bare earth, with perhaps a hearthstone or so." In another district, "house accommodation is both far too limited in quantity and bad in quality. . . . . It is the bounden duty of all proprietors to furnish a full equipment of substantial cottages, combining the requisites for comfort and decency, on all farms. Withheld, they stop the onward progress of social order, and hold out a premium to vice and degradation." In another district, "many are still compelled to live in wretched hovels." In another, "house accommodation is still deficient, in many cases consisting of one or two rooms only for a married man and his family."

Of the cottage accommodation in another district, an informant says that nowhere is it worse. "The cottages are the greater part mud-built and very small, and contain but few conveniences; and there are many instances where a whole family, sometimes quite a large one, have to put up with a solitary sleeping apartment—where the father and the mother, the boys and the girls, herd together, to the total destruction of common decency, and, consequently, to the detriment of morality." In another district the cottages of the labourers are "generally too small; and where a family is at all a large one, that leads to a sad state of immorality, from boys and girls, young and old, all being crowded together; and yet any increase of rent at once stops the labourers from attempting to lessen that seriously improper state of things." In another, "cottage accommodation has been sadly neglected." In another district, one of the greatest evils with which the labourer has to contend "is want of proper cottage accommodation; the miserable home, with but one bedroom and the sitting-room, is most prevalent; and you may travel through parish after parish, and scarcely find a cottage possessing three bedrooms; and so long as that is the case, however desirable the father of a family may be, or however much he may educate, we shall never find any moral or material difference ; wages may increase, means of comfort may increase, but so long as whole families herd together, there can be no benefit morally." "The house accommodation," in another district, "of the labourers of this county is far from what it should be. Of course (as in all agricultural districts) many of the cottages are old and ill-constructed, having insufficient sleeping apartments for a proper division of the sexes : whole families are huddled together, to the destruction of all moral and virtuous feeling."

By no means a difficult matter would it be to add to those pictures many others showing the condition of the cottage accommodation of our agricultural labourers, but space does not admit of this being done. We do not, however, ignore the fact that in many districts a fair state of sanitary completeness in cottage arrangement has recently been secured; but with all this, it is nevertheless true that, compared to what has to be done to bring up our cottage accommodation throughout the whole country to a proper standard, little, comparatively nothing, indeed, has as yet been effected.

But while the truth of statements such as the above may be readily enough admitted—and still more startling statements might easily enough be here given—the evils arising from the state of matters which they disclose as existing amongst us, may not be so readily granted. We therefore proceed briefly to point out what these evils are. And first, as to the physical evils : "The poorer classes in these neglected localities and dwellings are exposed to causes of disease and death, which are peculiar to them ; the operation of these peculiar causes is steady, unceasing, sure, and the result is the same as if twenty or thirty thousand of these people were annually taken out of their wretched dwellings and put to death, the actual fact being that they are allowed to remain in them and die. I am now speaking," continues the high authority from whom we are quoting, "of what silently but surely takes place every year in the metropolis alone, and do not include in this estimate the numbers that perish from these causes in the other great cities, and in the towns or villages of the kingdom. It has been stated that the ANNUAL slaughter in England and Wales, from preventible causes of typhus fever, which attacks persons in the vigour of life, is double the amount of what was suffered in the allied armies in the battle of Waterloo." These are no exaggerated statements as to this great battle against our people, which is every year fought and won; and yet few take account of it, partly for the very reason that it takes place every year. However appalling the picture presented to the mind by these statements, it may justly be regarded as a literal expression of the truth. "I am myself convinced," says the above authority, "from what I constantly see of the ravages of this disease, that this mode of putting the result does not give an exaggerated expression of it. Indeed, the most appalling expression of it would be the mere cold statement of it in figures." If the statistics of one disease can give such a fearful result, let us fancy, if we can, the aggregate amount of death caused by want of district and household sanitary arrangements throughout the kingdom. And in connection with these several evils, we give a most suggestive extract from one of the most recent reports of the Registrar-General:

"England is a great country, and has done great deeds. It has encountered in succession all the great Powers of Europe, and has conquered an empire in Asia. Yet greater victories have to be achieved at home. Within the shores of these islands there are thirty millions of people, who have not only supplied her armies and set her fleets in motion, but have manufactured innumerable products, and are employed in the investigation of scientific truths of the highest importance to the human race. Those people do not live out half their days; 140,000 of them die every year unnatural deaths; 280,000 of them are constantly suffering from actual diseases which do not prevail in healthy places; their strength is impaired in a thousand ways; their affections and intellects are disturbed, deranged, and diminished by the same agencies. Who will deliver the nation from these terrible enemies? Who will confer on the inhabitants of the United Kingdom the blessings of health and long life? His conquests would be neither by wrong nor by human slaughter, but by the application of the powers of nature to the improvement of mankind."

The evils arising from this state of affairs does not rest here; the moral evils are as appalling in their nature as are the physical. "The immoral influence of filth," says a distinguished philanthropist, "and discomfort has never been sufficiently attended to. That influence is in the highest degree anti-social. The wretched state of his house is one of the most powerful causes which induces a man to spend his money in strictly selfish gratifications; he comes home tired and exhausted; he wants quiet, needs refreshment; filth, squalor, and discomfort in every shape are around him; he naturally gets away from it, if he can." Another authority thus writes on this important point: "Virtue and vice are as dependent upon physical conditions as health and disease. There is a fixed relation between comfort and morality; and there is a terrible positive connection between physical and spiritual degradation." Corroborative of this, the evidence we could give would be most harrowing, almost unfit for publication, such a horrible state of affairs do statistical inquiries show. "In these wretched dwellings," writes John Kay, "all ages and all sexes—fathers and daughters, mothers and sons, grown-up brothers and sisters, stranger adults—males and females —and swarms of children; the sick, the dying, and the dead—are huddled together with a proximity and mutual pressure which brutes would resist. Where it is physically impossible to preserve the ordinary decencies of life, when all sense of propriety and self-respect must be lost, to be replaced only by a recklessness of demeanour which necessarily results from vitiated minds."

It is not easy to cultivate the finer feelings of our nature, amongst people who live in dens into which men of wealth would be ashamed to thrust their dogs. Conceive the morality of those who are "cribbed, cabined, and confined," all the grades of low humanity together; "thirty-seven men," says one, quoting a case, "women, and children, all huddled together on one floor." Under such horrid circumstances virtue is impossible; "and indulgence in vice, or the commission of crime, seems scarcely other than natural." How can our churches, our town missions, and our schools, work out their full results when we perpetuate places amongst us in which "large masses of the population grow up so immersed in ignorance and vice as to look at it with complacency, and to live in it without disgust?" What says George Goodwin, the editor of the *Builder*, one who has witnessed as much of the horrors of town shadows as most men: "Again and again would we assert, that as you lead men and women to appreciate cleanliness, light, air, and order, you make them better citizens, increase their self-respect, and elevate them in the social scale. By the miserable dwellings to which thousands in this and other great towns are condemned, we are impelling them downwards—an easy process—with frightful results. It cannot be too often repeated, that the health and morals of the people are regulated by their dwellings."

But there is another point from which to view the causes of public apathy on this important question of sanitary reform, and to which apathy we have already alluded. The benevolent and philanthropic do not, unfortunately, comprise the bulk of our thinking classes. These form a good, but small body. Another class exists whose name is legion, who can only be appealed to through the pocket. Men of this class have little sympathy with misery, but they have much with money. A man of this class may spend a pound to punish a criminal, but he would grudge heartily the giving of a shilling to carry out any plan which promised fair to prevent him from becoming one. Dirt and disease may commit their ravages as they list amongst the very poor, and his ear is closed to all appeals for their relief; but the moment you whisper to him that by doing so and so he can save money, you have his attention. Convince him that it will cost him less to keep poor districts clean than it will to allow them to remain dirty, and you have some chance of obtaining his hearty services in the cause. Now, we are far from deprecating this feeling. So far as it goes, it is a good one. Waste at any time is a folly; but, when a system brings about a waste at once of life and money, it becomes a crime. We should like to see this feeling working in conjunction with others of a higher kind; but we must take it as we find it, and work upon it to help us in the cause.

It is no very difficult thing, therefore, to prove that every death caused by the want of proper social measures, must be a loss to the community; all unnecessary sickness requiring the expenditure of money in the endeavour to cure it must be a loss; and where pauperism is increased by the untimely death of those who support families, that those who have it to pay must pay for its support. It is not because there is a difficulty in proving these truths; it is because men have rarely thought of them, that their influence has been so little marked.

"Let it be remembered that a sickly population is one of the most costly burdens of a state. Health is the poor man's capital in trade; and whatever deteriorates that entails a direct loss, and eventually a heavy money charge upon the community. The enormous amount of poverty and destitution in this country, and the consequent necessity for an impost of nearly £8,000,000 (eight millions) sterling annually for its relief, are in a great measure due to the pauperising effects of preventible disease."

Did space permit, we could cite abundance of evidence to put the truth of this startling statement beyond a doubt; but surely this is not required. There are some things need but to be stated to show their truth; this is one of them: "It is proved that the money lost through typhus fever alone in the metropolis, during the five years, 1843-47, was £1,328,000, and that this might have been prevented." To this add the loss sustained in other towns, and say whether or not the amount is not worth trying to save. From one disease alone, much aggravated by, and in many cases wholly due to, the fearful condition of the dwelling-houses of the poor, 60,000 die annually in England and Wales alone.

It is a mistake, and one the existence of which amongst us gives rise to grave evils, to suppose that all the work of amelioration, the direction of which we have endeavoured to point out, can be done, and done only, by large bodies governmental and corporate. For the truth is, that a vast power lies in the direction of individual exertion; not merely in connection with the dwelling-places, and the localities in which they are congregated, of the poorer and labouring classes, but in connection with the dwelling-places of the richer classes. It is quite a mistake to suppose that sanitary improvements in the arrangement and construction of dwelling-houses, and in the laying out and drainage of the districts in which they are built, are wanted only amongst the squalid class which exist so numerously amongst us. For, although in consequence of the houses of the well-to-do—as the phrase now is—being, generally speaking, isolated, or at least, not crowded together, the effects of the exciting causes of disease are not so strikingly malign as in the case of the confined and crowded districts of the poor; it is nevertheless true, that bad drainage, bad water, and bad air, cause diseases of the same class, but more or less modified, which act on the health of the inhabitants of the wealthy districts, as those which devastate the dwellings of their less favoured brethren. Nor should the fact be lost sight of, that what injures the poor reflects more or less immediately, but not the less surely, upon the rich. The diseases which sweep away the inhabitants of alleys, may—and in practice, unfortunately, are found too often to—spread to other quarters, and take death to the inhabitants of our squares and palaces. Hence the wide-spread interest which the subject of sanitary reform possesses to all classes; and hence the necessity that exists, if the true interests of all are concerned, to make sure that we carry out, as completely as possible, those arrangements in our dwelling-houses, calculated to insure, as far as may be, the health of their inhabitants.

We hope to be able to show that sanitary appliances are often wanted in the very best houses, and in the most favoured districts of the rich and well-to-do. And one great advantage which would arise from greater attention being paid to details of sanitary practice amongst these classes, would be that the influence of their example would spread gradually around; and the more numerous these examples would become in any district, still more numerous would they likely be.

But while censuring the richer classes for their apathy in the matter of sanitary reform, let us not fail to take note of the indifference of others. The work of amelioration is not, and should not be, all one-sided, and carried out by the better classes alone. The poor themselves have their share of the work to do, and it behoves them to look the fact fairly in the face, that they have not as yet in any complete sense done it. That work lies chiefly in aiding the exertions of those who are endeavouring to get the evils swept away which we have shown to press so heavily upon them, by doing all that can be done by the exercise of prudence, carefulness, and cleanliness. Now it is simply saying the truth, when we say that the poorer classes as yet have not done all they could in these directions. As to the habits of carefulness and cleanliness alone, they as a body have much to learn. The painful part of the matter is, that they too frequently show an utter indifference to the learning at all. We yield to none in our anxiety to raise the labouring classes to higher and purer life; but we are anxious to see that they do all they can to aid others in the task. It has been, perhaps, one of the mistakes of the past few years which has been committed by the richer classes, that they have by their various movements set forth the idea that everything had to be done for the labouring poor; at all events, that they, the poor, have little to do themselves in getting rid of the evils which surround them. We clearly see that there are some things which the poorer classes cannot possibly do for themselves. They cannot change noisome, ill-drained districts for healthy ones, nor wretched, tumble-down hovels for good ones; but they can do much when these things are done for them, to use them carefully, and to cultivate the habit of personal and household cleanliness, which will longest keep them in good order, and aid most effectually the health-securing appliances with which their houses are supplied by the care of others. It has been a matter of frequent occurrence, we regret to say, that the efforts of distinguished philanthropists to secure healthy homes to the poorer classes, have been thwarted and crossed by the poor themselves, and their efforts met with a languid indifference, or, still worse, an actual opposition, which has been calculated to lead to the deplorable result of inducing parties anxious to do all they can to aid in the establishment of a better state of things amongst the poor, to give up all attempts at it, seeing how vain the hope has been to get those most directly interested in the matter truly interested. Not seldom have we heard landlords and architects complaining, that after giving due attention to those constructive details and appliances best calculated to secure the health and the comfort of those who were to occupy the houses, they not only would not use these appliances, but would wantonly destroy them; or, by their habits of indifference and carelessness, make them inoperative. It is but a truism to say that the house may be a healthy one so far as construction and its conveniences are concerned, but that it will not be a healthy one if it is not kept clean and in good order. And to those who are not in the habit of seeing how the poor actually live, it is well to know that, bad as things are, so far as their houses are concerned, they are made much worse by the lack of order and the utter absence of all cleanliness which characterises so many of them. There are, we are glad to say, many noble exceptions to this, but it is just because there are exceptions that we insist that there is a capability on the part of all to make these exceptions the rule. If this were done, order would take the place of disorder, cleanliness of filth, and in many cases health that of sickness or disease. To those who are in the habit of making what are called "sanitary surveys," a phenomenon is very familiar as thus: In the very midst of houses and rooms, distinguished by almost every attribute that makes them disgusting to the refined mind, now and then there will be one house or one room met with, as markedly distinguished by the opposite characteristics. Poverty, truly, may stare out upon the visitor in everything that meets the eye—the "sticks of furniture" may not be worth a shilling or two, but order reigns everywhere; everything is very far from being of the best, but the best is made of everything—cleanliness prevails, and there are all the evidences of a determination to struggle with untoward circumstances, and not to be mastered by them. No one but he who has met with such "oases" of cleanliness and order in the "desert" of dirt and disorder by which they are surrounded, can have any conception how refreshing the fact of their existence is, to those who are truly interested in the welfare of the poorer classes. What, then, we have long contended, and now contend for, is, that it is the duty of the poor to increase the number of these excellent examples amongst them of what can be done to make good out of evil, order out of disorder, cleanliness in the midst of filth, and if things are bad that they should at least not be made worse by indifference and carelessness, nay, by positive injury done to property, with, if not malicious intent, certainly with a remarkable degree of carelessness as to what is done by others. For, to those who are acquainted with the poorer and working classes, it is not seldom a painful thing to see the wanton injury done to the houses in which they live. Children are allowed without remonstrance to write upon or mark walls, rub off paint, break plaster, cut and chip at doors and windows, and in many different ways so well known to the destructive proclivities of youth, injure property to a very large extent. The evil would be more easily remedied if its existence or perpetuation rested alone with children; remonstrance, and failing that, correction would influence children for good; but as neither the one is offered nor the other given by the parents, the inference to be drawn is, that the parents themselves are indifferent upon the matter, or careless to think rightly or act rightly about it. Noble exceptions, however, are found amongst the classes we are now writing about; and it would be a great service done to the bodies to which they belong if such who form these exceptions did all in their power to inculcate amongst their fellow-workmen the important truth, that while society owes a duty to them, they owe a duty to society; that while their rights and interests are respected, that they should respect the rights and look after the interests of others; and that drunkenness and reckless improvidence, uncleanly habits of person or in house, and carelessness of the property of others, act as injuriously upon themselves as upon society. It would be a great move in social progress, if the tone of the poorer classes generally was raised in this direction; and we know of no more potent power to aid in this than the influence of those of the working classes—and they are a large and increasing body—who, from their habits and high character, are an ornament to the class to which they belong, and would be an ornament to any class of society. If this influence were used, progress would be rapid in the social improvements of many of their own class. Nor should the lessons of the school be forgot, as bearing upon this point. Much influence lies within the province of the teacher, in bringing before his pupils the importance of what may be called the "ethics of sanitation," and every opportunity should be taken to impress these principles upon the minds of his pupils. There is much to deplore in connection with the habits of the people generally; and it would be well if the laws of health were made to form part of the daily lessons of the school. Frequent attempts have been made by philanthropists to bring this neglected department of education before the great body of teachers; but, we regret to say, with little practical effect. But we could go further, and maintain that the power of the pulpit should be brought to bear upon this important question—the duty we owe to ourselves in the matter of attention to the laws of health, and what is due to others in the direction we have indicated. As bearing upon this point, we venture to extract, from a daily paper, the following suggestive remarks, on what we conceive to be the duty of clergymen in the matter, much, if not all, of which applies equally to the teachers in our schools :

"On them (the clergy), especially in rural parishes, it greatly depends whether the powers so wisely conferred on parochial boards shall remain practically useless. And when they reflect on the innumerable mischiefs which may be mitigated or removed through the constant and judicious working of the Health Act, we trust that they shall feel it to be their duty to be vigilant in striving to save the lives of their parishioners by rescuing them from physical conditions which re-act on their moral nature, and render them deplorably indifferent to the display of whatsoever things are of good report. If it be chimerical to expect that sundry important Christian virtues shall be exhibited by those who are wretchedly housed, so that the labourer is readily lured from the muddle of his straitened hovel to the warm and tidy public house ; if modesty must disappear from a family accustomed night and day to look upon all that is unbecoming—the clergy, of all men, are the most interested in endeavouring to put an end to the physical obstructions which paralyse their spiritual labours. It is their duty to protest against these obstructions, not only in the comparative privacy of the parochial board, but in the congregation to proclaim that they are *sins;* and to appeal to the consciences of their hearers whether they will incur the guilt of culpable homicide by voluntarily continuing offenders against the law of the land, which at last, by enacting the wise and benevolent provisions of the Public

Health Act, has given such meaning to the aphorism, 'The safety of the people is the supreme law.' Indifference to sanitary questions is especially blameworthy in those who are bound to charge others to 'do good unto all men as they have opportunity.' While, therefore, we trust that the clergy will contend earnestly for the great verities of the Christian faith, we also earnestly trust that they will not be among the number of those who forget that man is of a twofold nature—bodily and spiritual—and who divorce religion from common life, and not as if they believed that there are many things with which religion has nothing to do."

It is, then, undoubtedly the interest of the poorer classes, as we take it to be their duty, that they should endeavour to get rid of the objection which philanthropists are often met with when, urging that something should be done to get rid of the evils which do press upon the poor, namely, that "it is no use doing anything for them, for let us do all we can, they are not a bit better." While by no means admitting that this belief should act so as to prevent them from doing good, we confess that it is powerful as an excuse for their indifference to it. By those on both sides of this important question, who take extreme views, we are aware that our remarks will be taken objection to; but we, nevertheless, believe them to be correct; and that, while on the one hand, granting that there are certain things to be done for the poorer classes which they cannot possibly do for themselves, we, on the other, are certain that the poorer classes can aid this work mightily by doing what no one but themselves can do; what, indeed, no one else ought to do. And thus we conclude that if society is bound to do something for them, they are bound to do something for society. We are not in any sense isolated portions of a great community; we are, in truth, bound up in the unity of a common interest. What is for the benefit of the poor man, is for the benefit of the rich; and, if we neglect to do that which is calculated to secure the health of those who dwell in the low, we will assuredly injure that of those who inhabit the high places of the land. The air we breathe, which comes alike to all of us, may be the medium of conveying to us the seeds of disease, as well as the support of life. It may float to-day amid the houses of the poor, laden with the miasma from ill-made, ill-arranged drains, or from dirt-heaps or cesspools where there are no drains at all; to-morrow, the wind may waft it to the houses of the rich, and the disease that was generated in the hovel, may next day break out with virulence in the hall. The river, the waters of which may be contaminated with the refuse from the houses of the rich, may be the source of supply to the houses of the poor, carrying with it the germs of disease and death to them. We thus see the close connection which subsists between all the branches of sanitary science, and how the influences to which they give rise are interchanged from one district to another, and act upon the health of all classes alike. No class possesses an immunity from the evils which neglect of the laws of sanitation bring into existence; all are subject to their influence. This may be, and is, modified by favourable circumstances; but it still is in existence, and may find a weak joint in the armour of the strongest. Hence it is that the importance of having a system of sanitary legislation, generally applicable to all classes of the community is becoming more and more understood; and we live in the hope that the various class and party interests, which have so long stood in the way of this system being carried out, will be at once and forever set aside, and that its establishment will be as speedy as these our introductory remarks, which we now conclude, have, we hope, shown it to be essential—essential from every point of view, physical, moral, and religious.

CHAPTER II.

HEALTHY ARRANGEMENT AND CONSTRUCTION OF DWELLING-HOUSES.

WE now proceed to take up some of the leading points connected with the subject heading this chapter. These will obviously be of a general character, as it does not come within the scope of the work to describe minutely those details which are specially within the province of the architect and builder. Numerous works are within easy reach of such of our readers as may be disposed to study the subject in its technical details, and to these we refer them.

The keenest critics of the work done in modern times, in connection with the arrangement and construction of our dwelling-houses, are architects themselves; and, although not disposed to go the length of one who, eminent alike for his taste in design and skill in construction, says that our modern structures are exemplifications of "how not to build," there is, nevertheless, ground enough to deal out some grave censures as to what is done in the way both of arrangement and the construction of houses. So far as the arrangement of the apartments are concerned, in their absence of proper means for lighting, and of those conveniences without which the most tidy housewife cannot be tidy, too many of our houses approach pretty closely the point of being exemplifications of "how not to arrange." And, so far as construction is concerned, in the choice of notoriously defective and unsound materials, in the absence of precautions to prevent damp, of arrangements and appliances to secure ventilation, and in the want of workmanlike care to lay down proper drains, and in such a way that they will remain sound and in good order, it may also be said that many come pretty well within the stricture we have already named, as examples of "how not to build." It is, however, only right to state that in many instances where but only too grave fault can be found in some of the above, and in other respects with the work of many builders, there has been no desire on their part wilfully to do bad work; but this has arisen chiefly from ignorance of, or careless inattention to, the points which constitute good work on their part. But there are others yet mixed up with the trade, only too well known as "jerry builders" or "sham contractors," and who are utterly incompetent to do good work, or even to know what good work is. Hence the number of houses which are erected, which are a disgrace at once to the constructive skill and to the civilisation of our people. These, it need scarcely be said, abound most in our large cities, and in our manufacturing towns; for the "scamping trade" has facilities there which it does not meet with in less populous localities, and in rural districts. The only remedy for such a state of things, which under better and strictly maintained sanitary laws would not be tolerated, is to be careful in the choice of the tradesmen who are to be employed in the houses you intend to build. Better advice still, secure the services of a competent architect. He may not come up to your notions of what a "planner" should be; but this he will secure for you, and that is a great deal, good work, which is the cheapest in the end. Another advantage obtained in the employment of a competent architect is, that he will be acquainted with the details of sanitary construction, by which the health of the inmates of the house may be secured as far as sanitary construction and arrangement can secure this. What these details are, it is now our duty to place in a general way before our readers.

And first, as to *site:* In crowded towns there is not much to choose, unless it be Hobson's choice—"this or none;" in suburban districts the choice is doubtless less restricted; but it is in rural districts chiefly that a variety of sites is offered to choose from. That the choice is not an easy one to make, or that an ignorance of what the points are which should dictate the choice too often exists, may be gathered from the fact that in many instances the very worst site is chosen and the best neglected. In considering the site of houses of a superior class to be built in the country; the term, it should be remembered, includes something more than the mere space of ground which the house is to occupy when it is built; it includes also locality of the site. As a general rule to be followed, the house should not be built in a hollow, or in the lowest part of a valley; rising ground, of easy ascent, should be chosen. But the position may be high in itself, as compared with some parts of the surrounding land, and yet low as compared with others. Thus Bacon —for that many-sided man has written on this subject also—says, "that you shall see that he who builds a fair house upon an ill seat, committeth himself to prison; neither do I reckon it an ill seat only where the air is unwholesome, but likewise where the air is unequal, as you shall see many fine seats upon a knap of ground, environed with higher hills round about it, whereby the heat of the sun is pent in, and the wind gathereth as in troughs, so as you shall have, and that suddenly, as great diversity of heat and cold as if you dwell in several places." An able authority has the following upon the points as to locality, which should be attended to: "Easy access to public roads and conveyances, with supplies of water and fuel, are indispensable requisites in the choice of a situation. Again, it is preferable to have a house sheltered by trees than by mountain scenery, because the former afford a cool and refreshing air in the heat of summer, and in winter they serve as a shelter from the keenness of the cold winds which periodically prevail; while mountains, especially if their position be directly east or south, are singularly disagreeable at certain seasons of the year, and only afford a partial protection from the winds." Some choose a depressed part as very likely to be a sheltered spot, but this is quite a mistake; for, independently of the difficulty there is in draining the house, the chances are all on the side of winds beating upon the house as angrily in its low situation as if it were placed upon rising ground near it. Stronger winds oftener blow through the lowest part of a valley than along its sides, or even sometimes upon the summit of the sides. The site of a house is often chosen on account of its proximity to a piece of water, this last being considered as "such a pretty object in the landscape." No doubt water viewed from a house, especially if surrounded with clumps of trees or wooing willows near its banks, is a pleasing object, but whether it is good to have it near the house is another question; it is more probably true that distance rather than proximity will lend enchantment to the view; and it is almost certain that actual proximity to water is not a healthy thing. As a rule, it will be found that delicately-constituted people rarely are in good health while living in houses in immediate proximity to water. The bad features of the case are intensified if, in addition to being near the water, the house is placed on a level with its margin; and worse still, as is sometimes the case, a little below it. The site of the house will in these cases be more or less damp, than which there is no greater evil to be encountered in a house. Again, do not build at the foot of a sharply rising ground, or near the face of a precipice. Some have chosen such a site as this from the idea that they would be protected from the north wind, utterly forgetful of the fact that not only would the site of the house be exposed to all the drainage water of the hill above, but that chimneys would smoke in nearly every high wind that blew, from its being drawn down or deflected from the surface of the rising ground behind the house.

It is to be noted that, while attention is to be paid to the general aspect of the site, the special aspect of the house which occupies it must not be overlooked. The site in its general features may be admirable; it may command the finest view, take in the grand aspect of forest and mountain, or the quieter points of river, lake, or rural scenery; it may occupy the healthiest position; and yet many of the advantages may be lost by not paying attention to the peculiar position of the house, or the site actually occupied by it. It is not enough to have a good site, then—it is necessary also to place the house upon that site in the best position. We have seen a house placed so that all the advantages of a fine view, which the site commanded, were utterly lost; or so placed that all the cheerfulness was excluded, all the gloominess secured. A little forethought would have avoided all this. Of all the aspects which can be given to a house, the south-east is the best—*i.e.*, the best aspect for the rooms which are most frequently occupied in the day time. This aspect is not only the most cheerful, but it is the healthiest—healthy, because cheerful—inasmuch as the cheerfulness is derived mainly from the large amount of light secured by the aspect; and light, or rather plenty of it, is perhaps one of the things most conducive to health. But while the south-east is as a rule secured as the aspect of the majority of the windows of the house, it will conduce much to the pleasure of its occupancy, if one at least of the living or entertaining rooms be provided with a window or windows having a due western aspect.

If the site selected has already its growth of trees, or if they have to be planted, it is of importance to consider their relation to the house which is to occupy the site. We frequently see trees planted right in front of the house, the very worst position which they can occupy; for if the prospect and aspect chosen are chosen upon the principle and for the reasons we have already explained, what can trees in such a position do but mar and spoil them? Trees always give dignity to a house when they flank, rarely when they front them. Nor should the degree of their contiguity to the house be overlooked, as overlooked it often is, although a point of great importance. Shelter is never obtained in its full and most useful effect from trees except when they are in masses, and masses always have a bad effect upon a house when placed near it. They exclude light and air, and create dampness; and to such an extent do they do all this, that we venture to maintain that, so placed, they always make a house unhealthy. Shelter is best obtained—we here speak of direct shelter—by the arrangement of the house itself, and its relation to the prevailing winds and surrounding objects.

The next point to be attended to is the soil of the site proper—that is, the space upon which the house is to be built. The best soil, as regards its general freedom from damp, and as regards its safety as giving a sound foundation, which will require little or no artificial material to make it so, is a gravelly soil. The next best is a chalky soil, although some authorities place this in the first rank. The worst is a close retentive clay. This is almost always a damp soil, and in many respects not a sound one for building upon. When the soil contains much loamy earth, or sand, precautions will have to be taken in order to secure a safe foundation. This is particularly true of shaley soils, which, although when first broken up appear as hard and firm as stone, soften very rapidly under atmospheric influences, and are often eminently unsafe. The same is true where the soil has shifting, loose beds of sand. The care, however, of an intelligent architect will always be given to this point of safety in the foundation soil. Special care will have to be taken in cases where the soil upon which the house is to stand is composed of "rubbish" or "made earth," which is the case in many town and some suburban localities. And here it may be pointed out that these "made soils" are too often most unhealthy soils, being, as they often are, composed of all kinds of rubbish, offal which is apt to decompose, and various offensive materials. Such accumulations are not fitted for the foundation soils of houses to be inhabited by human beings, more especially where sub-soil drainage, hereafter to be specially referred to, is not carried efficiently out. For in such cases the rain water —and too often the water of drainage matters—percolates through and amongst the rubbish, and forms masses of decaying matter: and if the sub-soil, or natural bed of soil, happens to be of impermeable clay, then the case is much worse, for the water accumulates in pools below, and adds to the danger of the mass. Drainage of the sub-soil is in such cases imperative; and every care moreover should be taken to prevent drainage water reaching the soil through defective drain-tubes, or by being thrown on the soil. There can be no doubt that the emanations from such soils, and under such circumstances as we have now described, must be highly injurious to health; and it is difficult to say how frequently outbreaks of disease, such as take place in peculiar localities, or in connection with certain buildings, arise from such circumstances. The choice of soil for the site of a house is one which should therefore be carefully attended to ; and that more attention should be paid to it is clear enough from the result of such investigations, all too limited, which have been recently made by physicians and architects in connection with it. Some of these, indeed, seem of a very baffling and contradictory character. Thus we have already stated, that according to almost universal authority, the best soils for house-sites lay between gravelly and chalky ones, some preferring the one and some the other, while all are equally agreed that a close retentive clay is the worst. Yet Dr Letheby, at a recent meeting of the Institute of British Architects, stated some remarkable results of investigations made by Professor Pettenkofer into cases of cholera, in which he was led to attribute the outbreak to the soils on which the houses were built. Dr Letheby pointed out two singular cases in which, while one part of a workhouse was visited with cholera, and many deaths resulted, other parts were free, the cholera cases being in buildings upon gravel, those buildings free from cholera being upon clay and brick earth. In another case, a large building was free absolutely from cholera, while all around the disease was raging, the building which was free being on brick earth, while the other houses were built upon gravel and made earth. But as if to show the difficulties attendant upon even such a comparatively simple question as the choice of soil for a site, Dr Letheby admitted that, while the investigation had gone to prove that clay soils were good as preventive of cholera, they were undoubtedly bad for a "permanent residence," as clay was provocative of rheumatism, phthisis, and other diseases produced by a damp atmosphere. This opinion brings us, we think, very much to that generally held as to the value of different soils for site purposes, and which we have already stated. The point to be attended to, so as to lessen the risk from cholera, is in keeping the soils free from stagnant water, sewage from defective drains, "and from variations in the level of the sub-soil water." This being attended to, the cause of cholera and fever outbreaks will be reduced to a minimum so far as the soil is concerned. That clay soils are *per se* damp soils, and that damp soils give rise to attacks of rheumatism, colds, and other diseases often insidious, there is no doubt of.

This brings us to describe the means of preventing houses from being damp, and under this head we venture to reproduce part of a brief paper which we wrote upon the subject for a leading agricultural journal.

There is no point to be attended to of so much importance in a sanitary point of view, as the *prevention of damp*, none so frequently overlooked, and, when thought of, so seldom thoroughly secured. And yet one would think it not so very difficult a matter to build a dry house. That it is difficult is, however, to be assumed, seeing how often damp houses are met with.

It is scarcely necessary to point out the dangers arising from the presence of damp, to the health of those who inhabit houses infested with it. Suffice it to say that these dangers are not the less to be dreaded because they are slow and insidious in their effects. The evil they can do may be long in doing, and frequently it may be, as it often is, attributed to other causes; but when done, it will be sure to be deadly in its effect. It will serve some useful purpose then, to glance briefly at some of the points connected with a subject so important.

As a rule, so little effectual are the means adopted to secure a dry house, that nearly all the plans proposed are in connection with the cure rather than the preven tion of damp and the cures; numerous as they are, are seldom thoroughly effectual. We rarely hear of houses which have been damp being made dry; the damp may be hidden or drained, but it is rarely thoroughly driven out of a wall, and a concealed foe is, in our opinion, worse than an open one. We believe that it is so practically impossible to change a thoroughly damp house into a dry one, that it is better to leave it at once, than throw away both one's money and patience in the attempt.

In the case of new houses, the plans in use to prevent damp are pretty numerous, but they are not all effective. The one most commonly recommended, and most frequently used, is the building in of a course of slate near the footing. The efficiency of this depends entirely upon the walls remaining sound, and upon their not settling. This, however, is seldom met with, settlement, to a greater or less degree, almost always taking place, and the cheaper and less carefully carried out the construction, the greater the chances of irregular settlement. The result of this is, that the course of slate gets out of line, and broken up and twisted; and when once this is the case, damp is sure to rise in the wall.

The remedy, or rather, to speak correctly (for there is in such a case no remedy), one way to get over the difficulty is to use a material so solid and impenetrable to damp, and yet so elastic, that if the wall do settle, the material will "give," to use the technical phrase; and while being twisted or bent out of its original line of lead, will remain unbroken in continuity.

Two materials are admirably adapted to secure these essentials, namely, lead and asphalte. We place lead first, because it is undoubtedly the best. If asphalte be used, it is essential that it be honest stuff, for there is, be it remembered, asphalte and asphalte, some material called by the name, possessing little else than this. It is necessary also to see, when good asphalte is obtained, that it be laid properly. This requires the exercise of some skill, which cannot, in rural districts, be easily commanded. Now, the laying of a layer of sheet lead all round the lower course of wall, near the ground, can be done by almost any ordinary workman; and, when once done, will form as effective a preventive of damp, as any material which can be used in this way. Where the expense of lead is grudged, and asphalte cannot be had, a good substitute for the latter may be obtained in a thick coating of pitch all round the lower course.

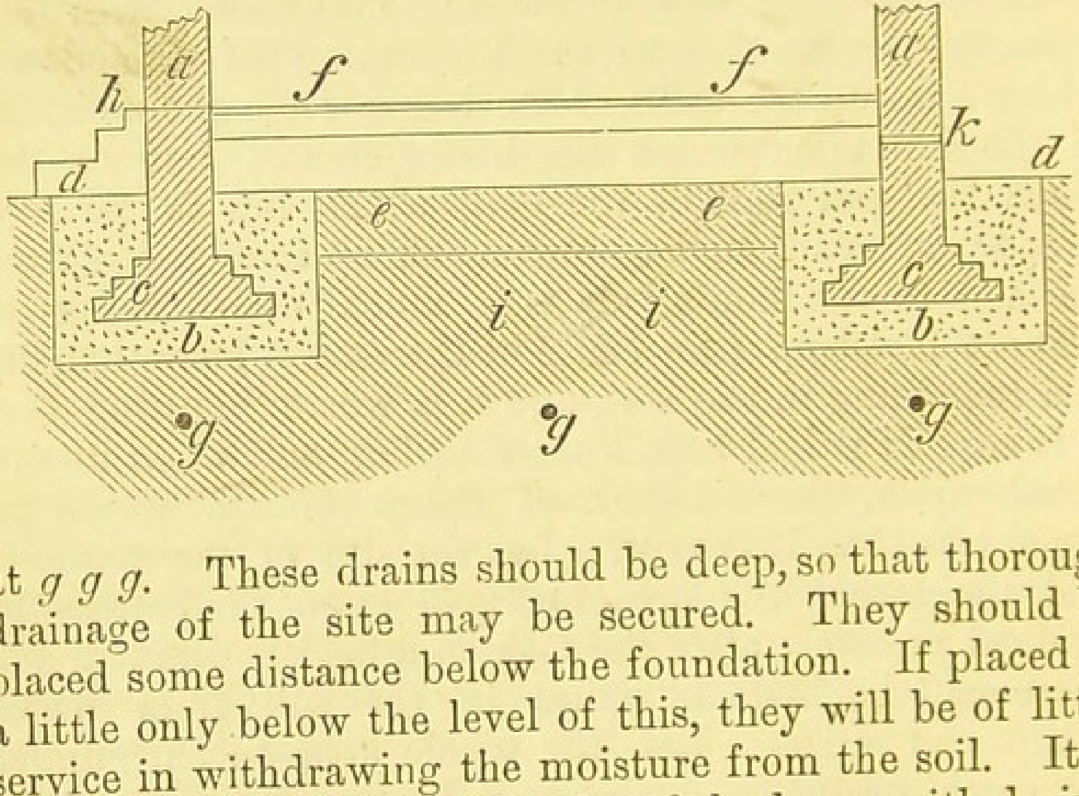
But these and all similar modes aim at preventing the damp from rising from the ground up the wall, and are only therefore so far effectual as the lowest courses of all, and the footing may be perpetually soaking in a damp soil. To secure dryness to the whole of the foundation courses (which is the most effective plan of preventing damp rising to the upper courses), it is necessary to surround the lower courses effectually with a material impermeable to damp, and strong enough to resist the pressure of the wall. This material is concrete. The usual way of applying this is to put it merely in the bottom of the foundation trench, and in a thin layer. The only effective way is not only to make the layer much thicker than usual, but to bring the concrete up both sides of the footings and to the level of the ground. The footings are thus encased, as it were, in concrete. But, as in the case of the asphalte, the concrete must be good, and the only concrete which can be thoroughly trusted to be at once lasting and impermeable to damp is concrete made with Portland cement. Here, again, in these days of adulteration, we have to interpolate the words, "the cement must be good." Good cement should weigh not less than 100 lbs. to the bushel, but we should recommend a heavier cement, as 110 to the bushel. The best material to use in forming the concrete is broken or rather crushed brick or small gravel; but it may be made with almost any kind of broken hard material, as "stone shivers," clinkers from smith's fires, breeze from ironworks, broken glass and crockery. Sand makes excellent concrete, even sea sand, although we prefer river sand or pit sand. The proportion of cement to the broken materials may be as low as one part of cement to six and seven of the materials. Where the finest, hardest, and most impermeable concrete is desired, three parts of cement should be used to seven of the materials; the cement and materials should be well mixed together with as much water as will make the mass sufficiently easy to be laid in the trench, and well worked close up against the stone or the brick forming the footings and lower course of the wall up to the ground level. As much of the concrete should be mixed as can be used at a time, as it has a tendency to "set" soon.

These methods now described, the reader will observe, have reference to the preventing of the damp which rises up the walls of the house from the moisture in the soil upon which the house stands, but do not touch the real root of the evil, which lies *in the soil.* It is by no means easy to prevent damp from rising from the soil to the house; it is a much easier thing to prevent moisture (the cause of the damp) from lodging and remaining in the soil, and it is worth knowing that it is so. If it had been known earlier, and when known acted upon, the number of damp houses would be much less than it is now. Let the site of the house—and the larger the area operated upon the better—be drained precisely after the fashion a field is drained, and there will be little moisture in the soil from which damp can arise. Let the whole area be surrounded by catch drains, and the area in the direction of its length or breadth, according to the fall or inclination of the ground, be divided into squares by parallel drains, all of which discharge their contents in the main drain leading to the outfall. We need scarcely say that the drains should be placed deep, not less in heavy soils than 4 ft.

6 in. The drains, or rather the trenches, may be filled up with stones if these be plentiful, or, better still, with the field drain tube.

In Fig. 1, we illustrate the principal points embodied in our remarks from the "*Field*," as before given, *a a* the walls; *b b* the concrete which is placed beneath the footings, *c c*; and which also extend up on either side of the walls to the height of the ground level, *d d*. The house will be all the more likely to be free from damp, if the concrete is extended from wall to wall as at *e e*, below the flooring joints, *f f*. The drains for carrying off the wet from the soil of the site are shown

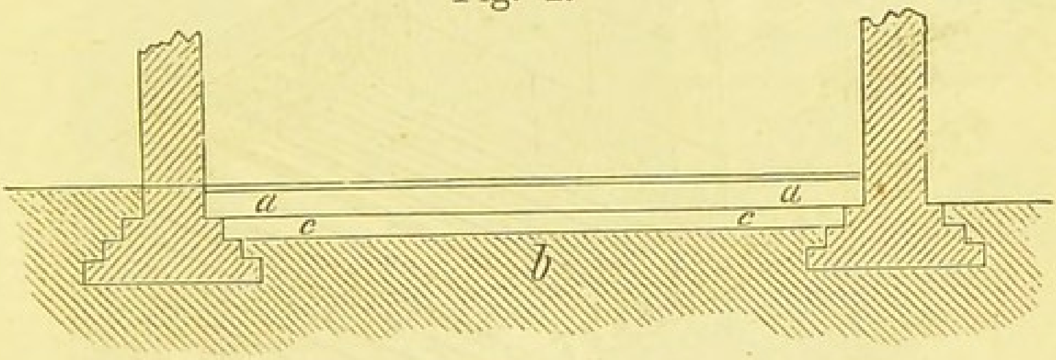
Fig. 1.



at *g g g*. These drains should be deep, so that thorough drainage of the site may be secured. They should be placed some distance below the foundation. If placed at a little only below the level of this, they will be of little service in withdrawing the moisture from the soil. It is not enough to surround the site of the house with drains, but they should lead across or along it, according to the declivity of the soil, the cross or longitudinal drains leading into the drains surrounding the site, and these again leading into the principal catch drain. A good elevation of the site, which we have already recommended, greatly assists the drainage. It is perhaps scarcely necessary to remind the reader that the site drains are the same as field drains for farm land, and laid down in the same way, that is, with the open joints, in order to admit the water from the soil which is led off by the sloping drains as soon as this collects; in this respect they act in one way precisely opposite to drains for carrying off the sewage of a house, which, as will be afterwards shown, must be impermeable.

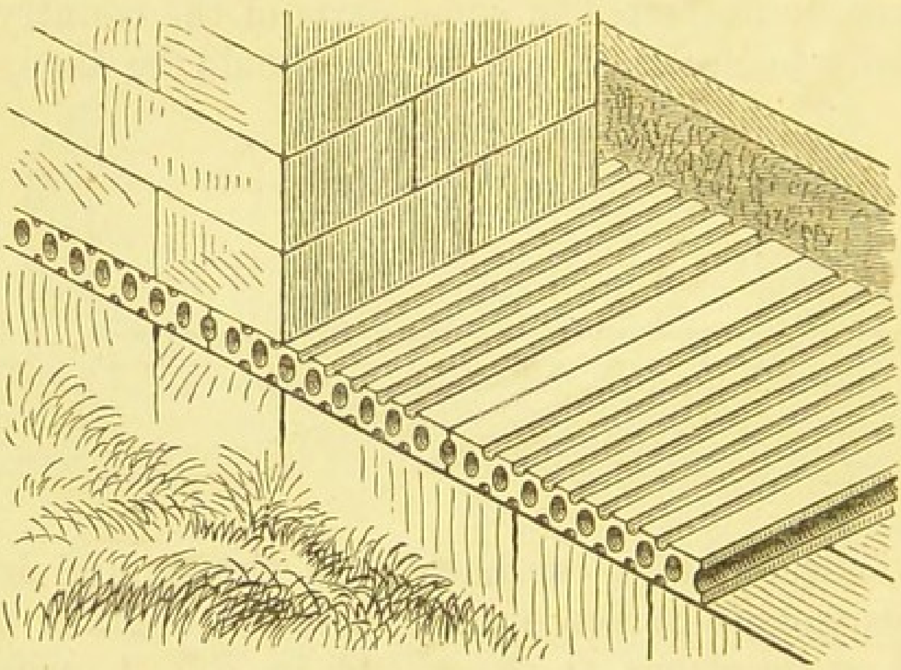
We must now point out the importance of raising the ground floor of all houses a height of at least two steps, as at *h* in Fig. 1. This is a precaution which is strangely neglected in some parts of the country, more especially in Scotland. A house should be always gone

Fig. 2.



up to, never entered at once from the ground level, or what is worse—as is too often seen—descended to from it. A mere glance at the sketch in Fig. 1, where the floor joists are well raised up from the ground soil *i i*, and those in Fig. 2, where the joists *a a* are quite close to the soil *b*, will show the difference which must be between the two houses in point of freedom from damp. The evil in Fig. 2 is attempted—but not always—to be cured by filling in the space *c c* with ashes—often only well-rammed soil—but it still remains. Another advantage obtained by having the floor well above the soil is, that a free circulation of air is admitted beneath the joists *b b*, as in Fig. 1, this being better secured by the insertion of air bricks, as at *k*. The expense of the plan in fig. 1 is no doubt greater than that in Fig 2, but it is trifling at the utmost, and should not be at all considered when health is thought of, as it should be. Even if concrete be used in Fig. 2, as in Fig. 1, the house will not be so free from damp, nor will the timbers be so well secured from "dry rot," as in Fig. 1; and if concrete, from motives of mistaken economy, be dispensed with, then the plan in Fig. 2 can only, if adopted, result in giving a house more or less damp. Free ventilation,

Fig. 3.



so as to carry off dampness, is unmistakably most certain to prevent dry rot assailing timbers, in preventing the germination of those microscopic fungi, which are the cause of it. These come into existence most readily where dampness, darkness, and quietness of atmosphere exist. These fungi, it is also worthy of remark, are profusely present in all decomposing vegetable and animal substances. It is not the actual wetness of a soil which affects timber, for water prevents dry rot, nor even air saturated with moisture, but the peculiar quality known as dampness, and which is best indicated by its peculiar odour; so that we say—and say truly—a place "smells damp." It is a condition which affects timber, and also all animal and vegetable matter which may be lying under the flooring timbers of a house, and the effects of which dampness may be called a slow combustion. Hence the necessity of getting rid of this insidious dampness by free ventilation; hence, also, the necessity of getting rid of all matter likely to decompose under the timbers of a house. People have little conception of the condition of the soil under some of their floors.

Fig. 4.

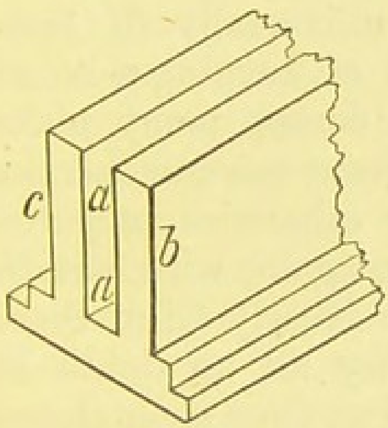
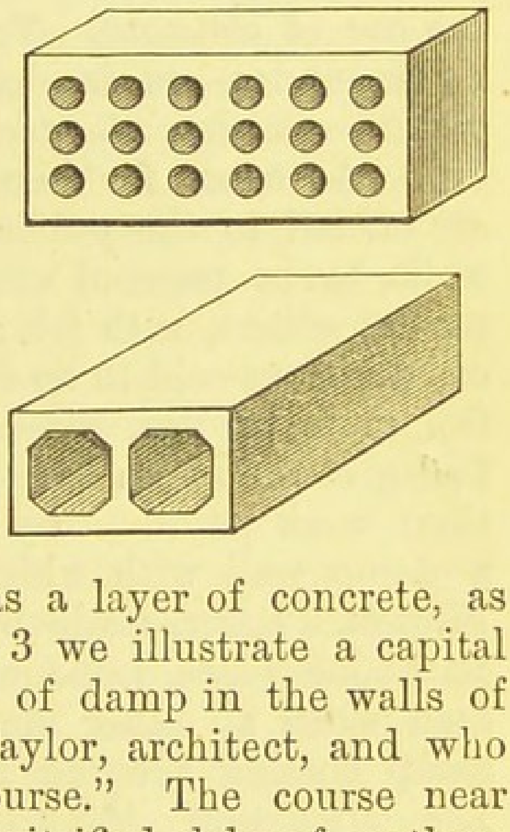


Fig. 5.

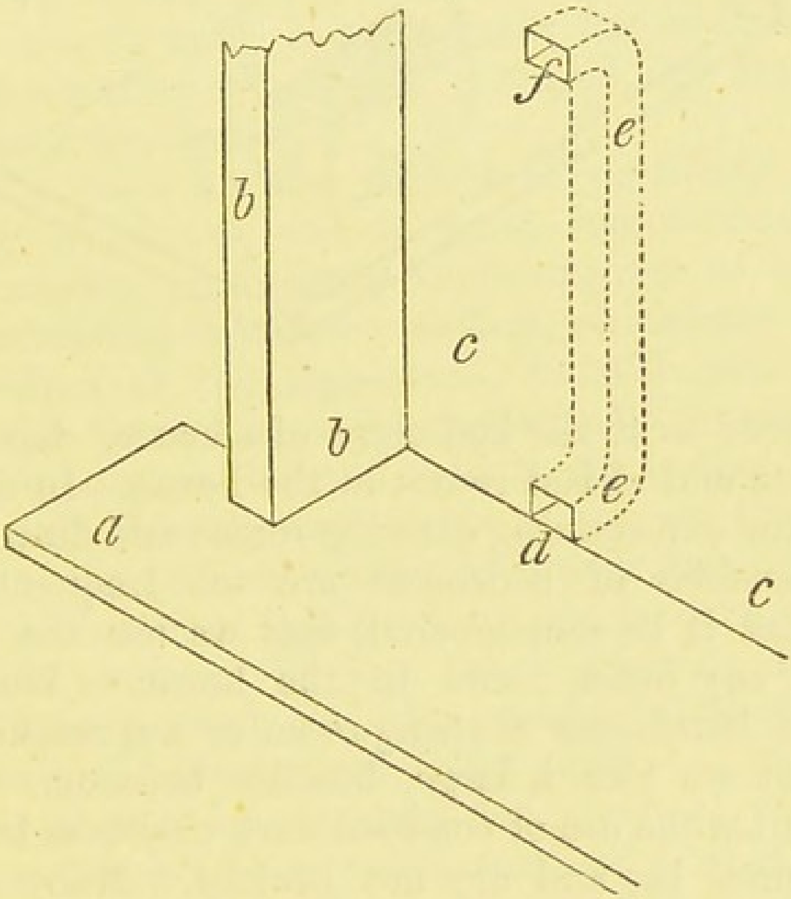


There is nothing so effectual as a layer of concrete, as illustrated in Fig. 1. In Fig. 3 we illustrate a capital contrivance for the prevention of damp in the walls of houses, the invention of Mr Taylor, architect, and who names it "the damp-proof course." The course near the ground-floor is made up of vitrified slabs of earthenware of various thicknesses, as one, one and a-half, and three inches, these slabs being hollow throughout. They are made of various lengths, to suit different thicknesses of walls. They are manufactured by the Broomhall Tile and Brick Company, Cox's Wharf, Upper Goswell Street, Blackfriars, London. To secure dryness in walls, they are now often built hollow, or with a cavity, as illustrated in Fig. 4, in which *a* is the cavity or hollow space. This mode of building is largely on the increase, as it tends to prevent damp from entering from the outside wall *b*, or the inside wall *c*. Hollow bricks, as in Fig. 5, are also now used for the same purpose. But it is obvious that, unless the soil be free from moisture, the damp will rise up in walls built hollow, as in Fig. 4, or with hollow bricks, as in Fig. 5, affecting the whole mass more or less, although it will not so quickly penetrate through it, as in the case of walls built solid throughout. The only true remedy is, first, the complete drainage of the soil in which the house stands, and the use of concrete. To cellar the whole or part of the house under—as is done almost universally in Lancashire—is also an excellent means of keeping a house dry. As cures for houses already damp, many plans are offered to the public notice. Some recommend the walls to be papered with tarred or otherwise prepared paper; others, with felt; and others, again, with certain compositions said to be damp-proof. Nearly all of these fail more or less, some utterly; they all no doubt at first give the appearance of success, but time soon shows their weak point. By far the best material to cure a damp wall with which we have met, is Desachy's Fibrous Plaster, made by Messrs G. Jackson & Son, 49 Rathbone Place, London. We have known this to succeed when all other plans had failed in preventing the damp coming through from a thoroughly damp wall. The *Mechanics' Magazine*, in an article in a recent number, speaks in the highest terms of a material to coat or paint surface of walls to prevent damp, and also to secure the stone, brick, etc., from the deleterious effects of the atmosphere externally. The substance is known as "The Impenetrable Solution," and is made by Messrs R. Gay & Co., of Alton, Hants. We have had no personal experience of this substance; but, from the terms in which the author of the paper above alluded to speaks of it, it may be tried with considerable chances of success.

Dr Letheby, in the paper already referred to, pointed out the influence of the character of the material employed in the construction of walls upon the health of the inmates of the house, alluding particularly to the evils arising from the use of a porous stone, which not only takes up damp, but also absorbs effluviæ, which being again given out, act injuriously upon the health of the inmates of the house. If bricks be used, care should be taken to have them of the best quality, hard, and well burnt. A good brick is a healthier material than the generality of stone employed for building. It is by no means so porous as, and therefore is less affected by, damp than stone; and the surface, when wetted by thorough rains, dries much quicker. We are aware this is all counter to received opinions in districts where stone is habitually used; nevertheless, it would be a comparatively easy task, were this the place for it, to prove the superiority of brick as building material, even in other respects than those above named.

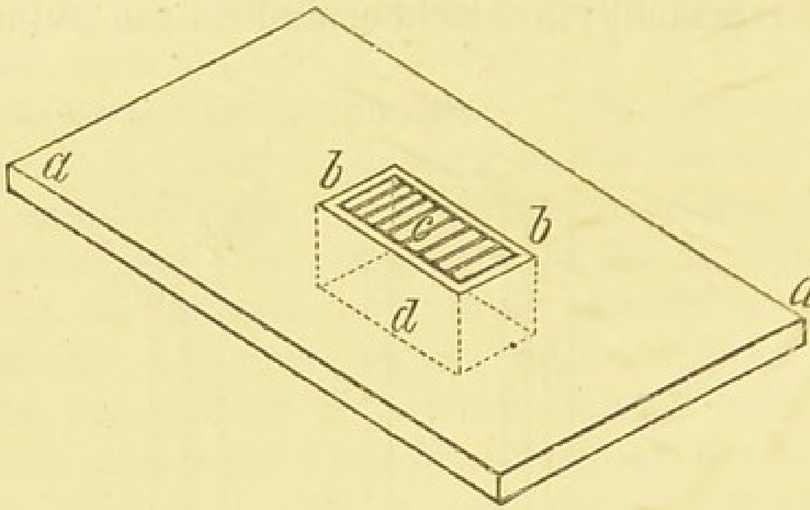
We now offer a few brief remarks upon some points closely affecting the healthy arrangement and construction of dwelling-houses. And first, as to light. It is only of late that a good supply of light to houses has been recognised as an important sanitary agent. Each apartment should, therefore, have large window lights. A well-lighted apartment is not only healthier than a dark one, but it is cleaner, or rather we should say, it is more likely to be kept clean. Dirt flies the approach of light; let the light therefore be ample, that every corner of the apartment be displayed, so that the excuse, too often given, cannot be held true, that the dirt was not seen. It may not be true that a light room is always clean, but it is pretty nearly true, in fact, that a dark room is always a dirty one. Even the most indifferent housewife does not like to see dirt and dust lying about, if it is easily seen; but the same housewife will easily allow dust to lie that she knows is there, but which, not being seen, does not offend the eye, and be to her a perpetual protest against its presence. The presence of dust in a house is not only unpleasing to the eye, but it is the cause of unhealthiness. The recent researches of a well-known *savant* into the composition of the dust floating in every, even the cleanest and purest atmosphere we have in our houses, will recur to the reader. Dust floating about the atmosphere of a house cannot be a healthy thing, more especially when we remember the foul materials from which it is often, we may say always, generated. An excellent contrivance for preventing the dust in a room in which there is a fire-place becoming a source of annoyance, is the "dust-draught," illustrated in Fig. 6. This is arranged so as to take advantage of the upward draught met with in all chimney flues (*see* next chapter, on Ventilation), and consists of a tube or flue *d*, built or formed in the back wall, *c c*, of the fire-place, of which part is shown at *b*. The lower part of this opens on to the back, in a line with the face of the hearth-stone *a*, and is led up at *c c* the back wall of chimney *c c* for some distance above the grate, and then is returned and issues into the chimney flue at *f*. All dust created by stirring the fire or sweeping the hearth, or even the floor in the neighbourhood of the hearth, is immediately caught up by the current, led up the flue *c c*, delivered by the opening *f* into the chimney flue, and carried finally into the atmosphere. This is no mere suggestive plan; it has been used for years practically, and is now in daily use in hundreds of houses; and few in the county of Lancashire are without it. We strongly recommend its adoption in houses about to be built. The plan may be adopted in houses already built by using a metal pipe, letting this partly into the back wall of chimney flue *c c*, Fig. 6. In conjunction with this we would also recommend the "ash grid" to be adopted, especially in kitchens and in the living rooms

Fig. 6.



of cottages. This is illustrated in Fig. 7, and in its simple form is a metal grating *c c*, flush with the surface of the hearthstone, fitting into the upper part of a small well-hole, *c c*. When the ashes and cinders are moved to and fro with the shovel, the ashes fall into the well-hole *c c*, and the cinders are left in the grating, from which they may be removed and added to the fire. It is a cleanly, economical contrivance, and wherever it forms part of the fittings of a house, it is valued highly by the housewife. If the kitchen is cellared under, it is usual to send the ashes down to the cellar by a special flue communicating with the grate opening at *b b*.

Fig. 7.



One word as to the bedrooms of a house. Let them be the largest and airiest rooms in the house. In the desire to have fine entertaining drawing-rooms and dining-rooms, the dimensions of bedrooms are too frequently sacrificed. Let it be remembered, that we use the bedroom most of any other room in the house. We do not despise a handsome drawing-room or a spacious dining-room, but we like a large, healthy bedroom. We are quite against the use of confined dark closets as bedrooms. They cannot be, and are not healthy. Many a severe cold is got by those whose business takes them out at an early hour in the morning without breakfast, or at least a proper one, at which time has been more or less leisurely spent in the freer atmosphere of a sitting room, by rushing out immediately after dressing, from sleeping for hours in a closet, into the cold raw air of a wintry morning. Workmen and others cannot help themselves, unfortunately, in this respect; but we must express surprise at those who " command the service of a heavy purse," spending one part of their evenings in a fine dining-room or drawing-room, of handsome and lofty dimensions, and thereafter rushing off to spend many hours in a small confined room, or, worse still, in a bed-closet! And yet in how many fine houses is this done —must be done—as they are planned? While on this subject, one word also as to the sleeping-places of servants. They are too often a disgrace to humanity. Shoved up to the slates, or sunk down to the cellar, they are utterly unfit, in many cases, for human habitation, and are often not so well arranged and fitted up as the master's dog-kennel.

We now take up the subject of dwellings for the labouring classes as one of great importance, and to which a marked prominence has been given of late years in the discussions of sanitary matters, which have occupied the attention of the legislature, learned societies, and other bodies interested in the welfare of the people. So much has been written and said in connection with the subject, and so well known, therefore, are the general features of the evils connected with their dwelling-places, and of the localities inhabited by our labouring classes, that space need not be here taken up with details on this at best painful and disagreeable subject, and to which we have already sufficiently alluded. Nationally, we know enough, in one sense too much of the evils of this department of our social economy; what is to be done now, is to remedy them; but how this is to be done, generally and efficiently, puzzles the wisest heads amongst us, and affords a problem in our social life which is exceedingly difficult to solve, if indeed the present and next generation can have any reasonable hope that it will in their time be solved at all. Much, doubtless, has been done, but what has been done to remedy the evils existing in connection with it is as nothing to what remains yet to be effected. The efforts made to remedy the evils have been only isolated ones, here and there met with, not by any means general. Spasmodic efforts may have also been made, for it is a remarkable peculiarity of us as a people, that we have periodic fits of a real desire to get rid of evils surrounding us; or perhaps it may be more fairly put, as it has been put, of fear for their results to ourselves. Hence come also periodic fits of energy—whole districts are influenced with a desire to "sweep these evils off the face of the earth;" but then come calmer considerations, and the matter drops gradually out of sight, and the evils go on as before, or worse than before.

On a subject so confessedly difficult to deal with, and so many-sided in its aspects, it is impossible, within the brief limits at our disposal, to do more than glance at some of the leading points of the subject; nor is more necessary, as our work does not concern itself with details of a purely technical, but with those only of a general, character, bearing upon the health and comfort of those who are to live in the houses.

Much of what has been already said with reference to site, soil of the site, prevention of damp, etc., etc., as connected with houses of a superior class, is obviously applicable to those designed for the labouring classes. What has been there recommended may be objected to on the ground of expense; but with this we have nothing to do. It is our duty to point out what we conceive to be essential to health, leaving to others the responsibility of refusing to carry the requirements out because they cost money. The arrangements relating to comfort and convenience may be dispensed with in the houses of our labourers, but they have a right to demand that those relating to health should be strictly carried out. A damp house, for example, cannot be otherwise than an unhealthy one, whether it be inhabited by a poor man or a rich one; and if our talk about providing healthy houses for the labouring classes be anything more than mere talk, it is our duty to see that all proper measures be taken to secure healthy arrangements in them. Plans may, however, be modified more or less, according to circumstances, and much efficiency may be obtained by carrying them out on a less costly scale than if designed for more expensive structures.

As regards the locality of the site, there is, in the majority of towns, no great choice; but all efforts should be made to have, if possible, the houses built away from the neighbourhood of those which are notoriously defective in sanitary arrangements, or inhabited by the depraved and the degenerated. We need not dwell on the importance of this, enough having been said in the first chapter to indicate the bad effects of sights and sounds of wretchedness in physical, and of degradation in moral, life. We hope to see the time when houses for the labouring population are well ordered in the matter of locality, as well as in that of healthy construction.

A great deal has been written on the point of building houses in rows and streets. There can be no doubt that what many authorities maintain is true, that the "row," or street system, is productive of bad social results, and that isolated cottages, each with its "bit of garden," are the best, from every point of view, both physical and moral. But we are a long way from realising this dream of philanthropy. We cannot, under present circumstances, —and they are likely to be the circumstances of several generations—dispense with the row or street system; but it is open to us to see that the best is made of it. The rows should obviously be so placed with relation to each other, that abundance of light and air be given to all the houses in each row. The blocks should be so designed that the accommodation of each house should be given with as little depth as possible, and so that a free ventilation be secured from front to back, or, rather, through and through the house. No central space blocked up from all ready access to air and light should be permitted, as is too often met with in the arrangement of street houses, especially in the northern parts of the kingdom. In connection with this point, it is an exceedingly suggestive circumstance, that while so much is being said as to the importance of providing healthy houses for the labouring classes of our towns, the municipal regulations of some of them are such, that they actually prevent healthy houses being built. A noted case in point was met with in a large and wealthy town in the north of England. A certain plot of land was to be laid out for the erection of labourer's houses, and the plans prepared by the town engineer were lauded by all as undeniably well adapted to give the most healthy arrangement to the blocks to be raised; but it was found that the plans "contravened the municipal building arrangements." We cannot find space to go into the history of the matter, but the point involved in it is so important that we deem it likely to serve a useful purpose by giving here an extract from a pamphlet written on the subject by one of the architects of the town in question. After pointing out that building regulations often hamper designs, and that when they have been complied with, the result obtained is precisely that which proper regulations would have prevented, the author goes on to say:

"But it is, as has been already said, much easier to find fault with present regulations than to suggest better; and it would be presumptuous to do more than indicate the direction in which they should aim. At present, they insist on a certain width of street in proportion to the height of the houses. This has given us a town like Manchester, with acres of streets in dreary sameness with stagnant air. Would it not be better to encourage variety in planning, narrower streets, opening out into wider spaces and squares, where the difference in temperature between the wider spaces exposed to the sun might draw the air from the narrower streets, causing draughts and movements of the atmosphere? It is clear that streets might be built closer and higher, if their ends opened out on parks and greens, without harming their ventilation, than if they were extended for square miles of regularly disposed street, and court, and house, though only two storeys high. This might be accomplished by fixing the proportion of space left open to ground built on, permitting builders to arrange their blocks as they liked, subject to conditions, of which the most important would be one which present building acts ignore, that there should be no stop-gaps to the circulation of the air, no dwelling-rooms opening out into wells or small courts, in which there is no through current. Such an arrangement might be difficult to adjust to work fairly. It would have a tendency to raise the value of property near public open spaces, which, however, is not unreasonable; and it might necessitate power on the part of the corporation to decide how streets should be laid off on private property, so that where one man had commenced a street it should not be blocked up by his neighbour, as happens in some of our English towns. But we doubt not, legal acumen could frame a regulation which would secure the desired result directly, instead of the present roundabout attempt at it, which provides streets of a certain width at every part, and yards of a certain size attached to every house, which does not always secure ventilation; and, though a good thing in some circumstances, is often unjustifiable waste. Again, it is obvious that in a short street, if it opens into wider streets, the house may be made high, and the width confined, without the injury to its ventilation, which would ensue if it were longer; so that there would be more reason in municipal regulations if they made the height of the houses dependent on the length of the streets, instead, as at present, only on the width."

From what has been said, therefore, it will be seen that the mere arrangement of blocks of houses upon the ground is one involving considerations of no small importance. It is scarcely necessary to say that the subject has not yet met with the attention it deserves; it is a very easy thing to point out whole districts in which blocks of houses are put down, in direct contravention of the laws of health—undeniable examples of "how not to do it."

As regards the internal arrangements in planning the labourer's house, a few brief remarks may be offered. In towns and their immediate neighbourhood, the price of land makes house-rents very high, and the accommodation in a labourer's house is often limited to the one room, which serves, or is made to serve, as kitchen, living-room, and bedroom. We need not enlarge upon the evils, both physical and moral, which arise from a system of living such as this. For a man and his wife alone, or for a single person, the one room may do, but comfortable and convenient living cannot be secured in it. When a family is added, the evils are intensified, and they give rise to disease, sickness, and all the other physical results of over-crowding, to say nothing of the moral evils which are also apt to be created under such circumstances. A man with a family should have at least one bedroom, and, if the family are well up in years, two—one for the boys and one for the girls. A living-room as separate from the kitchen—or a parlour, as some designate it—we do not conceive to be essential. As a rule, working people like to live in the room in which the fire is almost continually on, as in the kitchen; and in nine cases out of ten, when a parlour is provided, it is never used, or if used, only on rare occasions, and is much more frequently made into a bedroom or a lumber-room. A scullery, however small comparatively, we conceive to be an essential part of every labouring man's house. The more free from the annoyances which are unavoidably attendant upon housewife work the living-room or kitchen is, the better will the husband like it. Domestic work is not liked by men, especially that "black beast" of every house, the washing. A scullery admits of much being done which, if done in the kitchen, makes that uncomfortable, and brings about the marked contrast which it offers to the comforts of the public-house parlour, to which, be it remembered, many a working man flies, not because he is a drunkard, but because he finds attractions there in the way of a warm, clean, and generally well-ordered room, which he does not find at home. Cupboards or presses should be given, and as many as possible. A great deal of the *nous* of an architect is shown in the manner in which he gets conveniences of this sort in planning the house. Without them it is not easy for order to be kept in a house. If everything should be in its place, it is clear that there should be a place for everything. The room should be well lighted, and so placed with relation to doors that a thorough draught through the house may be established from time to time, the only mode of ventilation which in many houses is open for use. (*See* Chapter III., on Ventilation.) In laying out a building plot, space should be left for drying-places for clothes, and, if possible, small garden plots. The general idea seems to be, that the plot should be wholly built upon, forgetful of the true rule that the size of the building should bear a due proportion to the space upon which it stands. If this is attended to, there will always be space left for the purposes above named. It does not form part of the scheme of this work to enter into the question of planning with all its details, but we may venture the remark that, as a rule, planning is an art too much neglected. If it were studied more than it is, there can be no doubt of this, that we should have more numerous examples around us of houses having the maximum of conveniences and comforts at the minimum of cost. To those interested in what has been done by public bodies in connection with the establishment of labourers' houses in towns and their neighbourhoods, we would refer to their published reports, and to the pretty numerous works written on the subject.

Before concluding our remarks upon town houses for labourers, we would draw attention to the field of usefulness which lies before philanthropic bodies and individuals in repairing and altering old houses. While rejoicing at all attempts to institute a new order of house erection for the poorer classes, we think that in the renovation and restoration of old houses there is an exceedingly wide field, which calls for the exertions of the philanthropist and will repay the speculation of the capitalist. That the former is true, few, we think, will be disposed to deny; but some may be sceptical as to the latter—that such a plan of operation will do good all may agree, that it will pay, some may deny. We purpose, therefore, to show how the plan of renovating old houses, to make them fit for living in, may pay a fair interest for the money expended. This we cannot do better than give a practical example in a brief story about an old house.

There might be seen at almost any hour in front of it, in the broad glare of day as in more congenial darkness, a restless knot of men and women, clustering on the dirty pavement, and moving round the dark entrance of a passage to the depths beyond. If the spectator stood long enough to gaze, the knot would now and then become more restless than before, and in the air might be seen the uplifted hands of combatants, and across the space which separated him from the heaving mass, would come the oaths of hardened men and the shrieks of no less hardened women. This part of the street was at all times the dread of the quiet passer by, and it was hard to say whether the obscene jokes which in their peaceful moments they bandied about, were more jarring to the ear than the screams and angry oaths when a war took place. Mustering up his courage, we suppose the spectator to cross the street, and working his way through the knot of savage men and women—fit indication without of the state of matters within—he passes up the dark and filthy passage, bending as he goes to avoid contact with the low overhanging roof above, and feeling the unmentionable filth beneath; and, at last emerging from the dark and noisome place, to let his eyes rest on a mingled mass of rotting houses, of garbage foul and wretchedness extreme, which the light of day makes all the more hideous and revolting. Darkness would at least shut out to one sense the horrors of the place. From left to right, and all around, a mass of filth and pollution of every kind meets the eye, sending up its pestilential steam, as if in mockery of the patch of blue sky seen overhead between the masses of decaying building, telling of brighter scenes and purer air. On one side a building, the walls evidently in the last stage of decomposition, meets the eye—the clouds of smoke rushing through the apertures of glassless windows to meet the noisome air of the yard without, telling of the wretchedness within. On the right some wretched cellars, into which the light of day never enters, but the habitations of poor wretches, whose half-naked children, playing about the doors, give evidence of their condition. Further up in this sea of dirt, picking his way by what may be termed islands of more solid filth, the spectator comes in sight of some ricketty, tumble-down stairs, leading by a dangerous path to the storeys above, and beneath which are masses of filth unnameable. Working courageously his way, the visitor passes another ruin, from the open door of which issues the steam of cattle, telling of another phase in this land of wonders; and comes at last before a six-storeyed building of modern erection. This tenement, called ——— is a marked spot in the police records, and a well-known "manufactory of cases" for the infirmary. Entering the doorway, and climbing cautiously the stairs covered with the accumulated filth of years, the visitor meets on every side, and in every house he ventures into, a state of filth, wretchedness, and unblushing wickedness, which in its very intensity appals him. He wonders no longer at the knot of savage men and unwomanly females which covered the pavement at the entrance. The secret of their existence, and the cause of their perpetuation he has now arrived at; the samples at the entrance of the close do not belie their friends in the interior. To describe the state of matters as regards home accommodation could best be done by negatives. But having given the frame-work of the structure, we leave it to the imagination of the reader to supply the details. If they have read the accounts of similar places in other towns, they will have no difficulty in doing so. There is a remarkable unity in the stories of unsocial degradation. Such *was* the condition of this wretched place. Let us see what philanthropy, aided by well-directed efforts, has succeeded in effecting, and what the scenes which greet the eye and soothe the feelings of a visitor now. First of all, the knot of savages have disappeared from the pavement before the passage opening—if they came at all they would have to come from other quarters. Their dwellings, or their occupations, are gone now. On the site of the wretched cellars formerly alluded to, stands now a comfortably, nay, elegantly, fitted up coffee-house and reading-room for working men. To make it commodious, the cellars and the flat above them were appropriated, a height of ceiling of fifteen feet being thus obtained. "Few would imagine," says the benevolent projector, "that twelve months ago the floor of that room consisted of cold wet mud, affording nourishment to Irish filth and squalor in all its luxuriance. Never shall we forget," he continues, "the contrast between sitting beside the comfortable fire, with a bowl of excellent soup and a number of the *Illustrated London News* before us, and the recollection of having a few months ago, on the very spot where we were then sitting, stumbled, amid the darkness of that horrid cellar, over a wretched woman in the last stage of consumption. She was lying on the floor in a few rags, and surrounded with pools of water, the essence of the polluted close, which had run down the steps and lodged on the uneven and already saturated floor." The second feature in the scheme is the "renovated dwelling-houses" for the working classes, with water, gas, water-closet, and bleaching green. The houses are nine in number, and are situated in the front house. There are three houses at a rent of £8, 10s., consisting of two rooms and a kitchen, bed closet, and coal closet. These look to the street. The other six look to the back, and consist of two rooms and a coal closet. All the sleeping apartments are well ventilated. The rents of the two small houses are £4 for the lower storeys, and £3 for the upper. Each tenement is provided with a water closet. On examining the condition of the old houses, "their dilapidated appearance was so apparently irremediable," that the proprietor never contemplated their renovation, but at once took estimates for their removal, and the building of a better class of houses on the site. The cost of this was given at £400. This being a much larger sum than would have been necessary for the building of a similar house in an open space, a close examination was instituted, to see whether, after all, renovation were practicable. Having consulted practical men, the proprietor proceeded to remove the whole interior, alter the height of the floors, and, in fact, renew the interior in every respect. The expense of this was as follows:—

Masons' work	£54	0	0	Lathing & plastering	£33	0	0
Carpenters' ditto	117	0	0	Sundries	13	0	0
Plumbers' ditto	24	0	0				
Slaters' ditto	5	0	0	Total	£247	0	0

The rental amounts to £35, showing a return of 31 per cent., including the original value of this renovated portion, £70. The following is a comparative return between building the new house and renovating the old one:—

Cost of new house	£350	0	0	Cost of old house	£247	0	0
Rent of ditto	35	0	0	Rent of ditto	35	0	0
Per centage. 9¾.				Per centage, 14.			

It is right, however, to mention that had the house been built anew increased accommodation would have produced a rental of £40, showing a return of 10 per cent. On the other hand, the peculiarities of the old house rendered a larger outlay necessary than under other circumstances might have been the case. Here, then, we have homes fitted up with every convenience, yielding a return quite equal to that of dwellings of the most ordinary description, and in point of accommodation every way superior. We are glad to say that this plan of making defective old houses into good ones is rapidly spreading in our large towns. In London there are some marked examples, showing how successfully the system has been carried out.

We now come to the subject of cottages for the labouring classes in rural districts. From what we have said in the first chapter, the reader will have gathered that there is ample scope in this direction for the exertions of the philanthropist and the sanitary reformer. But it is only right to state that, as a rule, more has been done in erecting a better class of cottages for the labouring classes of the rural districts, than has been done in erecting houses for the same class in the towns of the kingdom. But notwithstanding what has been done, a vast deal yet remains to be done before it can be said that the labouring classes are well housed in the rural districts. But it is somewhat unsatisfactory to know that of what has been done, it would have been better for the sanitary movement in this direction, had much of it not been done at all. For, as we have elsewhere remarked, in one of the leading journals, while describing this subject—"As in many things extremes meet, so in this matter of cottage reform, landlords, from the period of giving labourers nothing in the way of good healthy accommodation, rushed into an opposite extreme of giving them too much. And this arose from bringing to bear upon the question a standard which had really little or no connection with the matter, viz., the standard of wants and tastes of landlords rather than that of the labourers. Many ventured wildly into cottage planning—would that all of them had stopped at that stage—and cottage building, without ever asking the question or having it asked for them, what are the habits, tastes, and modes of living, and what consequently are the wants and necessities of the class for whom we are about to build? The habits, tastes, and mode of living of the labouring classes—be they right or be they wrong, and that is not the question we have at present to concern ourselves with—are not those of the class or classes who have larger or deeper purses, and wider wishes and aims in life. Hence, judging by this false standard so set up, cottages of or for labouring men were deemed to be—under the new philanthropic régime—structures, in which accommodation and fittings were necessary, which, if a more judicious and correct standard had been taken, would at once have been seen to be anything but necessary, quite indeed in the opposite direction. What was wanted was the cottages with only the accommodation required, and the style and kind of fittings wished for by the classes who were to inhabit them, designed and built so as to be comfortable and healthy. This was in truth the maximum of requirements ; but more, much more was thought of, and in a large majority of instances given, so that the expenses of erection were so high, that after a time men began to fear the outlay, and, as a consequence, a lull took place in the 'steady desire of beneficent philanthropy.' Well, things for a period were left very much to run in the old groove of doing nothing. Again, a very insane feature was allowed to characterise the cottage improvement question, namely, the adoption of a rigid—a Procrustean—rule, by which the circumstances of the labourer had to square themselves to the accommodation given in his cottage, not the accommodation squaring itself to the circumstances of the labourer. Those who are intimate with the literature of the press and the platform utterances in connection with this question, will remember how gravely on almost every occasion where these utterances were delivered, it was propounded that in every cottage the 'least acommodation necessary was a living-room and wash-house, a scullery and three bedrooms ;' and to prove the necessity of this rule, unvarying in its application, very stirring statements were made, showing the evils arising from overcrowding, from sons and daughters sleeping in the same room together, or, what was worse, in the same room with their father and mother. Now, these evils no one wished to dispute, as we do not wish to dispute them now ; but the question, and apparently a very common sense one, was never asked : Do the cases for which we intend to build come within the category where these evils can exist ? What if the cottage is to be inhabited by labourers who have no family ? What are *they* to do with the plethora of apartments ? A very little consideration would have sufficed to show that such a rule deciding what accommodation was wanted in a house never was applied, never could have been carried out in a paying direction, in the homes of other classes ; in these the accommodation has reference to the size of the family, or it may be stated the converse way. *Cottages with varying accommodation* should have been the rule from the beginning of the agitation on reform ; and because it was not the rule, expenses were gone into which tended very generally to convey the idea that cottage building was not, and could not be, a paying concern ; and which, therefore, operated strongly as a deterring cause in the case of those who otherwise might have gone into the matter practically. No doubt there are those who have all along maintained, and still maintain, that the building of good healthy cottages must not be dealt with only, if at all, on paying, but on purely philanthropic, or if not philanthropic, upon prudential considerations. Now, while not by any means ignoring the value of such considerations, it is of no use to put out of court those connected with the paying capabilities of cottages. The wish to make them pay is perfectly legitimate, and does not of necessity preclude the wish to give place to philanthropic consideration. Patriotism and philanthropy are all very well, and we should be the last to say anything to the contrary, ; but the purse will and ought to have its claims considered. The surest ground to tread upon in urging forward this important movement, will be that in which philanthropy and profit can both meet, and each find its wishes realised. And we are of those who believe that this sure ground can be got ; but it never will be got, if the dictates of prudence are lost sight of in the future, as we venture to say that they have been greatly lost sight of in the past. That they will not be lost sight of in the future we have some signs around us, as the whole subject is being viewed in a much more practical way. Men are beginning—if they have not already in many instances begun—to see that the questions are not, what would we, who are going to build cottages for our labourers, like ? but, what would they for whom they are be to built like ? not what is the standard of our habits and tastes ? but, what is the standard of theirs ?—not that we follow rules, which somehow have been considered as good, we know not how or why, but whether these rules are in reality good ? not what must we do what we wish to do, but we must do what is wanted. Let us not be misunderstood, in saying that one of the points to be considered is the standard of the tastes and habits of those for whom the cottages are to be built—we do not overlook the fact that this standard may be, and in point of fact is, lamentably low. What we mean is, that this standard is, in points that are right—as there are unmistakably points which are right—should be considered, and where it is wrong it should be modified." We see no reason to change the views which we held when we wrote the above some years since—every day, indeed, in connection with the present position of the question inclines us to believe that these views are correct. If more acted upon, improvement in the direction of giving good cottages to the labourers in rural districts will be much more rapid than it has hitherto been.

Much of what has been said in the preceding paragraphs of this chapter, on the site and the arrangement and construction of houses in towns, applies to those houses in the country; but a few remarks on points applicable to the latter only, or chiefly, will be here necessary. And first, with reference to the water-closet. This we have no hesitation in saying should be outside, not necessarily far from the house, as at the bottom of a long garden, but outside ; and although we use the term *water*-closet, we mean this as a general term ; for we advocate the use of the old-fashioned privy for country cottages, and this, if for no other reason, that the difficulties attendant upon the use of the closet in which water is used are so great in rural districts, that they cannot be easily, if at all, got over. A constant supply of water is not generally at hand, and when this supply is intermittent, it may fail precisely at the moment it is required, and this failure is sure to bring about the very evils which the water-closet is supposed to provide against. The whole subject, however, will be gone fully into in a succeeding chapter. The privy should be placed in conjunction with the ash-pit, a communication being made between them, and the coal place and wood and lumber-store next the ash-pit. We need scarcely say that of course we advocate the giving of a garden-plot, however small, to each cottage in the country. We need not dilate upon the advantages derivable from this addition. These are both physical and moral, and will be obvious on consideration. In the garden-plot should be placed a small piggery and poultry-house.

As regards the accommodation of the cottages, we have already indicated our views on this point sufficiently to state, that we advocate a due consideration of the probable requirements in this direction of the parties who are to use them. The minimum accommodation will be a living room or kitchen, a scullery or wash-house, and a bed-room. We have a decided objection to bed-closets, and if used they should only be used when special means to ventilate them are made ; but it will be better for the health of the inmates of the cottages if they be "conspicuous by their absence." This opinion is backed by that of able medical authorities ; and so important are the considerations which they urge, in a sanitary point of view, that we add here the important testimony of a well-known medical authority on this point :—"We are beginning to recover from the absurd plan of cramming our beds into small closets, in order that they might be out of sight and out of the way. Architects, a few years ago, seemed to think that the public rooms could not be too large, nor the bed-rooms too small, provided only a dressing-closet was attached. A third part of the twenty-four hours we spend motionless, and exhaling the rankest and most fœtid part of our cutaneous and pulmonary secretion in a small and confined bedroom, in order that we may shiver and starve in a large room during the rest of the day that we remain in the house. How often has the physician to regret the confined bedroom in which his patient is placed! Often it is impossible to ventilate it by raising the window, without risking the full draught of cold air on his patient. I have more than once seen the convalescent from fever cut off by pneumonia, from being exposed to the currents of cold air from a window raised a little to refresh him, or to ventilate the room. Alcove beds are improper, from retaining the foul air; the bed should stand in the middle of the room, and not in a corner, yet so as not to be in the draught from door to window or chimney." Another feature in the accommodation required in a cottage, is the store-place required for provisions, and nothing so completely comes up to the standard of excellence required in a store-place as the dry cellars so commonly met with in Lancashire and the North of England. These are there considered essential even to houses of the most ordinary description. They keep meat in a good state of preservation for a much longer time than can be done in pantries or meat-safes placed on the level of the ground-floor. Indeed, wherever their advantages have been experienced, they commend themselves at once to the common sense notions of housewives, who know the economical advantages obtained from a good provision store.

The dimensions or sizes of the various apartments is a point of considerable importance. The difference in cost between a room that is so small and cramped that all the domestic work is carried on with difficulty, and one in which, while too large and unnecessary a space is avoided, space sufficient is given to carry on all the work of the house with ease and comfort, is so small, that it should never be allowed to be taken into consideration. The least floor-surface given to the living room or kitchen, should be one hundred and forty-four feet: a room twelve by twelve feet will give this—a better proportion will then be fourteen by twelve. The placing of the door affects the size of the room very much, according to its position; thus, if put in the centre of the side or end wall, it cuts up the space on each side of it, that little room is given for placing furniture; but if placed in the corner, one large side space will be given. In closets, or small bedrooms, the doors should never be made to open into the smallest room, always into the largest room. The same rule holds with reference to doors of inside passages; these should always open into the large room. The least floor-space for a bedroom is one hundred feet; a room ten feet square will give this, or twelve by nine feet. The height of the rooms should not be less than nine feet from floor to ceiling. If the cottage is to contain larger accommodation than a living room or kitchen, one bedroom and scullery, say with two additional bedrooms, it should be built of two storeys. The bedrooms will thus be free from damp, warmer, and the cost of building will be less than giving all the accommodation in a single storey, as the roof will be less costly, the extra expense being in the walls only, and the roofing of these will be cheaper than a large roof to a one-storeyed cottage. As to attics, we should earnestly recommend builders to have nothing to do with them. They cost a great deal for the accommodation they give, and are cold in winter and hot in summer.

Next in importance to the building of new cottages, is the improvement of old ones. Indeed, it is questionable whether a more generally improved state of matters with reference to cottages would not be brought about more speedily by attending to the improvement of old rather than the building of new cottages. As this could be effected at little cost, and the improvements rapidly carried out, attention would be more quickly drawn to the matter, and the advantages would be more obviously seen, of having arrangements calculated to secure the requirements at will of domestic comfort and social decency. "It is," says a writer in the *Quarterly Review* for April, "at times a much greater kindness, and far more economical, to add to or repair an old house than to set up a bran new one. The special convenience of tenants can thus be much better met, and we should not find, as is the case sometimes in model cottages, some poor old body mourning over the uselessness of a large, cold room, or the desolation of unoccupied bed-chambers. Every sort of accommodation, from one room to six, is needed for a village population. No one could be expected to erect new buildings to meet all those contingencies, but a considerate attention would easily find means of satisfying all reasonable requirements by repairing and altering existing houses." "We would give up," says the writer we have already quoted, "much of the regularity and trimness of a martinet village for marks of individual kindness and consideration. While new cottages built here and there take the place of those that are utterly decayed, we should like to see this cottage patched up for Widow Toogood, where she and her old man have lived for more than half a century; that bedroom added for poor Tom Longleg's increasing family; that little shed knocked up for Jolter, the carrier; an extra bit of green allotted to Dame Twoshoes, who takes in the washing; a little lean-to permitted next his son for old Master Creeper, who needs no house of his own, and cannot hobble up stairs. These things show the real personal superintendence of one who cares for the people committed to his charge, and not the mere activity of an agent."

CHAPTER III.

THE VENTILATION AND HEATING OF HOUSES.

It is to the ventilation of private and domestic structures—these chiefly that we propose to direct the attention of the reader. In doing so, we purpose explaining the methods which are generally in use, and which have been found more or less successful in operation, more by illustrations and brief practical descriptions than by explaining the theories on which they are founded. The history of the art abounds in much that is interesting and useful, and the reader interested therein is referred to other works which treat specially thereon, as "Bernan's History of Warming and Ventilation." The atmosphere is composed of nitrogen ($75\frac{1}{2}$ per cent.) and oxygen ($27\frac{1}{5}$th per cent.), the proportion being one of nitrogen to four of oxygen, with a small per-centage of carbonic acid gas. There is another constituent of air made known by recent researches, and which is known as ozone—discovered by Schonbein—and so called from its having a strong odour. In the opinion of some chemists, the evidence of the existence of this constituent in the atmosphere is slender, still more so as to its influence upon health. The air, when drawn into the lungs, gives out its oxygen, or life supporting principle, to the blood, while the carbonic acid gas and other impurities are given up to be expelled from the lungs in the act of respiration, the carbonic acid gas in the expelled air being increased eight or nine times, the oxygen to one-half nearly, the nitrogen remaining as before.

When air contains three and a half per cent. of carbonic acid gas, it is incapable of supporting animal life. How closely the air in the condition in which it is expelled from the lungs approaches this deadly condition may be learned from the fact that it contains nearly two and a half per cent. of carbonic acid gas. The necessity, therefore, of getting rid of breathed air from the apartments in which we live will be apparent, but it will be seen as we proceed that there are other sources of deterioration in our dwellings, hence the necessity is still more imperative if the claims of health be attended to. There is, however, much to be done in this department of sanitation before we know the exact influence upon health which each agent in foul air has upon the system. Thus, nitrogen is assumed to be destructive of life, but as an able authority puts it, it is only a "negative respiratory poison," as being non-oxygenous it cannot perform oxygenating functions, whereas carbonic acid gas is a "positive respiratory posion." What is the proportionate influence or power of each of these influences positive and negative? We cannot tell with anything like precision, so that inquiry might be pushed in this direction with good results. The air thus discharged from the lungs has received a certain quantity of moisture —about which more presently—and an accession of temperature; hence the tendency which it has to rise up, and hence also the reason why all places disposed for its exit from any apartment are placed, as a rule, at its upper part. Respiration is, in fact, combustion. "Life is a slow combustion. The food we partake of is converted into blood, which contains hydrogen and carbon. The combustion of these is produced by the combination of the carbon of the blood, with the oxygen of the air inhaled into the lungs. The only difference between the combustion of any noticeable kind, as that of a fire or candle, and the various component parts of the human body is, that in the latter the process is carried on much more slowly, yet not the less certainly." The celebrated continental chemist—Liebig—estimates that fourteen ounces of charcoal are burned daily within the human body. The above theory is correct enough, yet it does not account for various phenomena observable in investigating the used air in houses For a long period chemists held that the constitution of the air in crowded towns differed very little from that in the country. The general feeling is opposed to this view, and its truth is evidenced by the researches of Dr Angus Smith on the air of towns, a gentleman who has contributed a large amount of practical facts on the subject of "Sanitation." These researches show that, in addition to the chemical change undergone by air which has passed through the process of respiration, there is another source of vitiation arising from the presence of an appreciable organic substance of a poisonous kind.

"The air," says Dr Smith, "has often been called a general receptacle all impurity; nature has made it a universal purifier by giving it so large an amount of free oxygen. It is oxygen which purifies, and bodies which are impure have a tendency to volatilise, after which they become pure.

"No doubt the air of a town contains a portion of all exhalations which arise in a town. These are such as come from living bodies in the first instance, exhalations which can never be got rid of, but which it is probable are not at all dangerous, unless accumulated. There are also exhalations from the refuse matter of animals and from combustion of fuel. These are the chief points. Various manufactures give out various effluvia, and no man that has walked through a large town with attention can have failed to perceive that no street is entirely free from effluvia, and that every one seems to have a peculiarity of its own.

"The smell is a delicate guide to this, and although custom causes us to forget that odour to which we are much exposed, a frequent change gives us still more acuteness, and both houses and streets may fairly be complained of when the inhabitants are little aware of it.

"That animals constantly give out a quantity of solid organic matter from the lungs, may easily be proved by breathing through a tube into a bottle, when the liquid, or condensed breath, will be collected at the bottom of the bottle; or by breathing through a tube into water, when a solution of the same substance will be found in the water. This would scarcely require proof if we considered that breath so frequently has an organic smell; perhaps, rather, it always has an organic smell, and when it is bad, the smell is often offensive, containing decomposing organic matter.

"If this condensed breath be put on a piece of platinum, or on a piece of white porcelain, and burnt, the charcoal which remains, and the smell of organic matter, will be conclusive. If it be allowed to stand for a few days (about a week is enough), it will then show itself more decidedly by becoming the abode of small animals. These are rather to be styled animalcules, and very small ones certainly, unless a considerable quantity of liquid be obtained; they may be seen with a good microscope. Animalcules are now generally believed to come from the atmosphere, and deposit themselves on convenient feeding places, that is, they only appear where there is food or materials for their growth, and they prove, of course, the existence of that continuation of elements necessary for organic life. At the same time, their presence is a proof of decomposing matter, as their production is one of the various ways in which organised structure may be broken up. Such liquid must, of course, be an injurious substance, giving out constantly vapours of an unwholesome kind."

That the deterioration of the air in apartments in which human beings are present, by the exhalation from their bodies alone, must be considerable, is evident from the fact, that about an ounce-and-a-half of aqueous vapour is passed off per hour from the lungs and skin of each individual on an average, and the whole of this nearly is of an unwholesome character. This is made evident to the sense of smell, the odour being particularly disagreeable; and this all the more marked if the individuals are not in a healthy condition. This increased mal-odour arising from the unhealthy condition of the individual is well known to medical men, some diseases, as that of small-pox, having odours almost, if not altogether, peculiar to them. The ounce-and-a-half of aqueous vapour given off by the lungs and skin of one individual is sufficient to saturate three hundred and sixty-six cubic feet when the temperature of the air is 66°, and when this comes in contact with colder surfaces, as walls, doors, windows, this is precipitated, and water trickles down their surfaces. The condition in which this water is, has been already indicated in the matter already quoted, as given by Dr Angus.

Air in apartments is also deteriorated by the combustion of gas and of candles. The gas-lights may vary much in the quantity of gas they consume, but each jet has been set down as consuming more air and deteriorating it than a man, a candle being equal, or thereabouts, to one man. These estimates are, however, excessive, although it is better to err on the safe side. No doubt the noxious exhalations from these are chemical, not organic, but they nevertheless tend materially to contaminate the air of the room in which they are consumed. Further, the air in dwelling-houses is contaminated by exhalations from drains and sewers, and frequently from decaying organic matter left carelessly under the floors, and from damp walls and floors, and sometimes from the decomposing bodies of vermin which have died—often by the effects of poison—and which remain in the crevices of the floors, walls, or partitions. The sources, then, of contamination in the atmosphere of our houses are not few, and all of them are too prolific of evil.

Nor does the evil cease in all cases, by the mere withdrawal of the foul air from the interior of our apartments and the supplying thereto fresh air—so called —from the external atmosphere. For that, although called "fresh"—meaning thereby pure, for the terms are generally used as synonymous—is not always pure, but often the reverse of this. This holds more particularly true of the air of our manufacturing towns, which is contaminated by the emanations from factories and workshops of various kinds. Some of those are deemed to be particularly noxious on account of their disagreeable odour, so bad indeed as to create sickness in some when inhaled. But it is not always the worst-smelling air that is the most noxious; often indeed the most deadly offend the sense of smell the least, so that the air of a neighbourhood may be deteriorated to a much greater degree by the emanations of a factory which does not smell so badly as those from another, but which, from their bad odour, may have the worst reputation. Under the auspices of inspectors appointed by Government to see to the carrying out of the provisions of certain Acts of Parliament relating chiefly to chemical works, a variety of experiments have been made to test the impurities imparted to the atmosphere by the emanations from industrial processes. These tests have been made by examining the quality of the rain-water in the districts in which these are carried on to a large extent, the impurities being taken up by the water, and thus presented in a form very easily examined. The result of the examinations made, we may here state broadly, was, that the air is greatly polluted by the emanations from chemical works; thus, in a gallon of rain-water taken from near a chemical work, no fewer than five grains of sulphuric acid were obtained. But the air is polluted greatly by emanations other than those from chemical works, notoriously, the smoke of factory chimneys. Coal used in the manufacturing districts contain more than one-and-a-third per cent. of sulphur, and the "produce from such coal is injurious to plants, and if to plants, surely to animals also." One hundred cubic feet of black smoke was found to contain thirty-three and a-half grains of sulphurous acid—the product of the sulphur in the coal; but as evidence of the waste going on by the production of smoke in the way so unpleasantly familiar to the dwellers in the regions of "the chaos of eternal smoke," we may state that the same number of cubic feet of black smoke contained no fewer than eighteen and a half grains of soot. But besides the sulphurous acid, this smoke contains other gases—as carbonic, oxide, hydro-carbon, and olefiant gas. The air of towns contains also a notable quantity of ammonia, produced partly by the combustion of coal and partly from the decomposition of organic or sewage matter—thus, a ton of rain-water collected in Manchester had one hundred grains of ammonia; rain-water collected in Newcastle had about the same proportion; in Glasgow, rather less; and in London, about half the quantity.

We have thus shown very briefly, but still, we trust, very suggestively, how numerous are the sources by which the air we breathe in our dwelling-houses, and while congregated in public buildings, is so deteriorated and, to an extent, more or less dangerous, and none the less so, that they act insidiously, and, acting so, one takes much less notice of them than were they more palpable to our senses. "We rid ourselves," says an author, very suggestively, while descanting on the subject, "of liquid and solid refuse by drains and otherwise; avoid the dirty and diseased, object to wear a garment worn by another, remove impurities from our food, and refuse to drink from a cup pressed by the lips of a friend; yet in our dwellings, and in our places of public resort, we continually draw into our lungs the offensive effluvia emitted from the lungs, skin, and clothes, not only of ourselves and friends, but of the promiscous crowd." Truly, if the air we so freely take in, while in apartments of various kinds, could be made palpable to our senses, we would shrink back in disgust from the loathsome and dangerous contact.

But, as may be gathered from what we have said, the obtaining of pure air to supply dwelling-places is by no means the easy matter it to some may appear to be. In some districts there is really no such thing as pure air in the neighbourhood of the houses. Even, as has been suggestively asked, if the people lived in the open air, would the air they breathed be pure? The answer is in the negative, so far as many town districts are concerned. Every medical man of much experience will give evidence that there are some districts totally inimical to health, and that on account of the impurity of the air which surrounds the dwellings. Nothing can be done, in fact, with certain "cases" without a change of air. How that may be secured under certain conditions by local arrangements we shall see as we proceed to the consideration of other departments of sanitary science. Meanwhile the fact is unfortunately too true that there are some districts in which the mere ventilating, so called, of the houses will not give the health which might be looked for under more favourable circumstances.

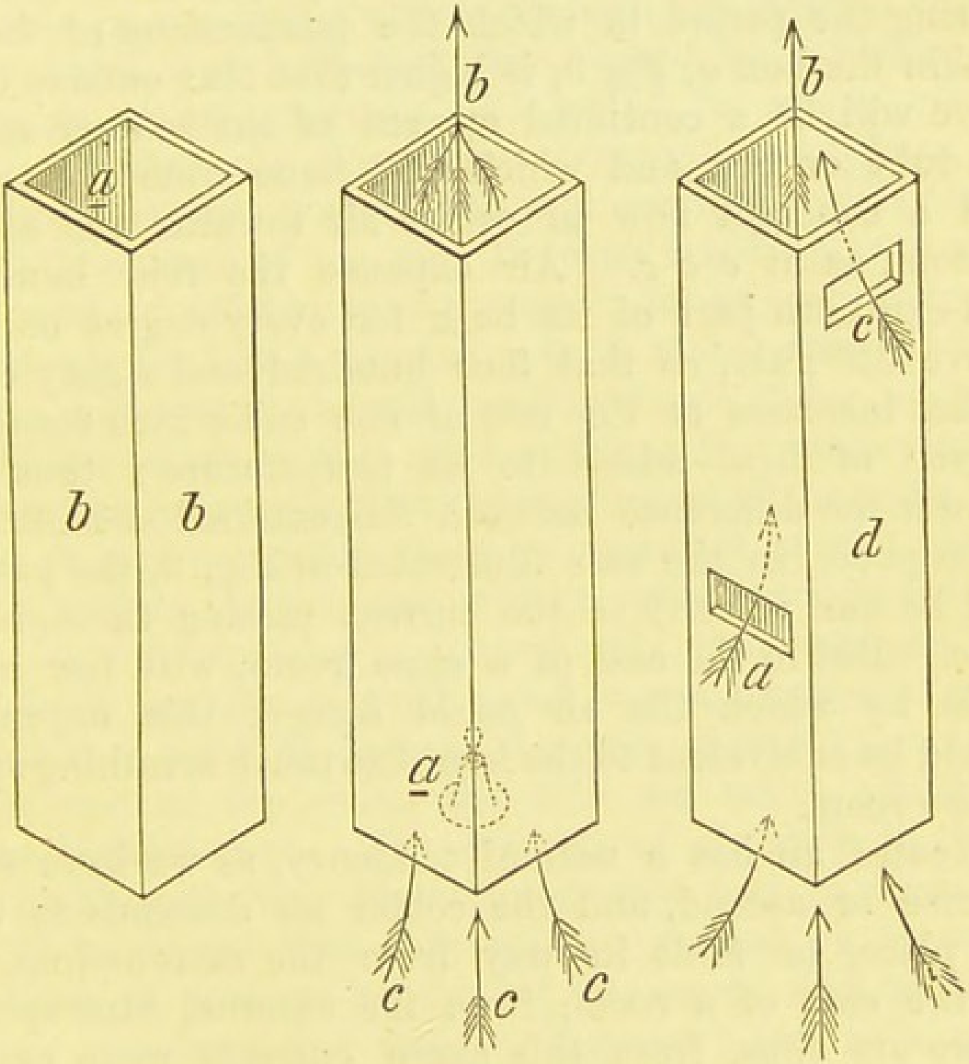
In proceeding to explain methods by which the deteriorated air is most easily removed from the interior of our apartments, we deem it necessary, at the outset, to draw attention to one important point—the overlooking of which has been the cause of so many failures in practice; this is, that apertures or means of ingress for pure or fresh air must be provided, as well as those for the egress of that which is deteriorated. Ventilation, to be perfect, or to approach perfection, must therefore include those two points—they must, in fact, work together, or no good results will be obtained. The foul air cannot be withdrawn from the interior of a building, unless fresh air be supplied to it; and, conversely, fresh air cannot be supplied as readily to an apartment, unless the foul air be regularly withdrawn. Ignorance of these essentials, or neglect of them when known, is a fertile source of disappointment in the ventilation of buildings.

The amount of fresh air required in an apartment, in which human beings live, depends upon circumstances. The usual or average number of inspirations a man takes in a minute is twenty, and the volume of air inhaled each inspiration is equal to forty cubic inches, giving eight hundred cubic inches as the volume per minute which is expelled from the lungs in a foul condition. This volume is calculated to render unfit for being breathed, a volume of fresh air equal to twice the amount, or sixteen hundred cubic inches. This is nearly one cubic foot, and represents the volume of fresh air which is required to be supplied to an apartment every minute, in order to replace the foul air which should be withdrawn to make room for the fresh air, or say sixty cubic feet per hour. So that if a man was enclosed in a box, ten feet long by two feet wide, and three feet broad, he would use up the whole of the fresh air which it would contain in an hour; that is, supposing he could assume such a position as to breathe the fresh air only, without having it deteriorated by the foul air. The higher the box, the longer he would breathe fresh air—the foul, as before said, having a tendency to rise to the upper part. But the law of diffusion of gases would bear upon the position, and the confined man would, by the spreading of the breathed amongst the unbreathed portions of air, become to be under the influence of the breathed air long before the unbreathed air was wholly consumed. The case here named is no doubt an extreme case; but, nevertheless, extreme as it is, it approaches closely, too closely, to the circumstances under which a very large proportion of our people live out their days, or sleep through their nights, in the spaces in which they are cribbed, cabined, and confined. But this sixty cubic feet per hour does not in reality represent the amount of air vitiated. It is—directly and indirectly—vitiated to a much larger amount; equal to 2880 cubic feet per day of twenty-four hours according to one authority, to no smaller a volume than 4320 cubic feet according to another authority.

From our illustration, however, it will be seen that the smaller the space in which a human being dwells, the greater is the necessity for *frequently changing* the air within it. In the best buildings, the allowance of cubical space for each individual is 600 cubic feet; but, even with this, the air, to be perfectly healthy, will require to be changed every three or four hours, as it only contains a volume of air which, under the most favourable circumstances we can conceive, would give a supply of fresh air equal only to ten hours consumption. We need scarcely say that these favourable circumstances are not often realised in practice. In the Lodging House Act, 240 cubic feet are allowed for each individual; but, in the Model Lodging Houses, this is increased to 550 cubic feet—a much better allowance, but still too small. In barracks, 500 cubic feet is the recognised space per individual; in hospitals it varies from 1000 to 1500 cubic feet. The necessity, therefore, for a continual change of air in our apartments will be obvious. But, if the withdrawal is too rapid, currents or draughts will be created; and, as in this climate the external atmosphere during a large portion of the year is colder than the temperature which is pleasant to the human body, these draughts or currents are cold, and are therefore still more disagreeable. Almost every one has a dislike—and in view of the dangers which they bring to the health, we confess a well-founded dislike—to draughts, this being more especially marked amongst the poorer classes, who almost invariably associate the admission of fresh air into their rooms with cold, and therefore discomfort; so that if they have the chance they will close up any ventilating apertures which may be provided in their dwellings. This notion or prejudice, call it what one may, which exists so strongly amongst the poorer classes, is, indeed, the difficulty in the way of providing ventilating appliances in their houses; and however much we may declaim against what we may call "the unfortunate prejudice," we have it as a fact to deal with, and the only way it can be dealt with, under the circumstances, is so to arrange the ventilating appliances of their rooms that they cannot render them inoperative. But to be just in our dealing with this view of the case, it must not be concealed as another element of difficulty in introducing ventilating appliances as part of every dwelling; that the "unfortunate prejudice" above alluded to, so long held by the lower classes, is not confined to them, but spreads itself pretty extensively amongst the middle and upper classes. No doubt that much of the association of discomfort and danger to health from draughts, with plans of ventilation, arises from the many unsuccessful attempts to carry them practically out. Nor need we wonder at the number of these unsuccessful attempts, when we consider how difficult a thing it is, to come up to the popular standard or requirement of personal and household comfort. Very few of the so-called unsuccessful attempts have really been so; that is, the majority of them will have been found, on examination, quite capable of giving ample supplies of pure or fresh air. But, then, it would have also been found that it had not been given in the way the people wanted it, and we may say in the way in which it should have been given to them. So long as the giving of pure fresh air to our houses gives also feelings of personal discomfort, so long will the popular opinion against it be so powerful that ventilation will be the exception, and not the rule, in our dwellings—no matter how much may be both written and said in favour of it, no matter how appalling may be the statements as to the evil sarising from the want of it. Hence it is that ventilation as demanded alike by the habits of body and thought of our population, is really by no means the easy thing to accomplish as some have talked and written about it. Given, a room so close and confined that the presence within it for even a short space of time of but a few people, renders its air decidedly prejudicial to their health; required, a plan by which pure breathable air shall take the place of the impure, and in such a way that there shall be no perceptible currents of air; and that the currents, gentle as they are desired to be, shall not carry with them the feeling of cold, or the idea of danger from draught. Such is the problem to be solved. Has it been solved? Probably in some few isolated cases, where expense was no object; certainly not so solved as to be generally at the command of the people.

And here one point naturally arises—Upon what does the success of ventilation depend? We have named one of the requirements, let us glance at the other. And to enable us intelligently to do this, let us first look at what may be called the theory of ventilation, as that may help us the better to understand its practice. When air, in a confined space, as within the interior *a*, of the box or

Fig. 8. Fig. 9. Fig. 10.



tube *b b*, Fig. 8, is of uniform temperature throughout, and of the same temperature as the air without the box, there is no movement of the air within it; the density of the internal and external air being equal; but the moment this equilibrium is disturbed, and a difference between the temperature of the air within the box, in the direction of an increase of temperature, and that without it, a movement of the air within the box takes place. This difference of temperature may be made by various means, as the placing of a lamp as at *a*, in Fig. 9. The air in the box at the lower part expands, rises, and flows out at the upper part, *b*; colder air entering the box at the lower part, as shown by the arrows at *c c c*. During the period in which the temperature of the air within the box *a*, Fig 9, is higher than that outside of it, there will be a continual current of the warmer air up the tube or box, and which will issue from the top, *b*, and a constant flow of colder air towards and at the bottom, as at *c c c*. Air expands the four hundred-and-eightieth part of its bulk for every degree of heat above 32° Fah., so that four hundred and eighty cubic inches increases at the rate of one cubic inch for every degree of heat added to its temperature; thus the greater the difference between the external and internal atmosphere, in the case illustrated in Fig. 9, the greater will be the velocity of the current passing through the tube. But in the case of a close room, with few apertures by which the air could escape, this expansion would be equivalent to the loss of so much breathing space in the room.

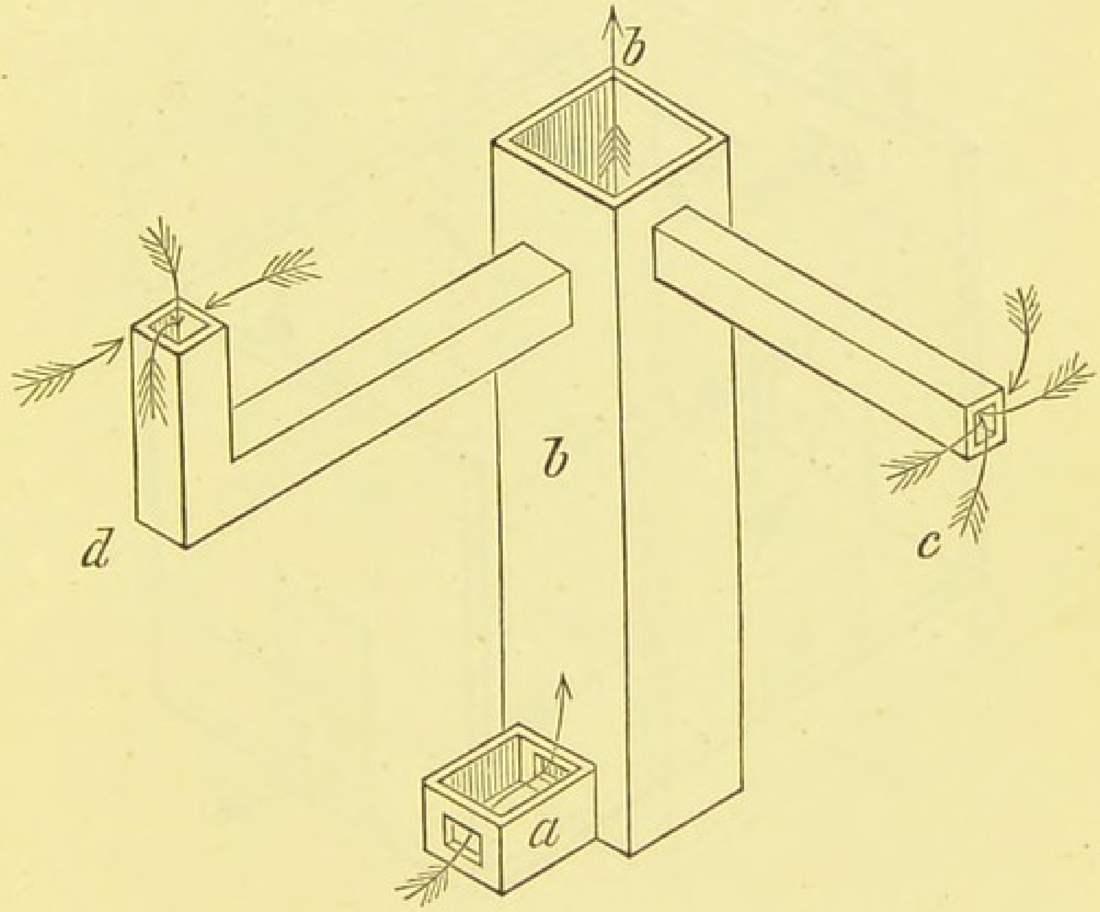
Heated air has a natural tendency, as we have seen, to rise or ascend, and the colder air descends to take its place, or finds its way from the surrounding, or, in the case of a room, from the external atmosphere. There are thus, from this cause, currents more or less marked in intensity, according to circumstances, going on within the interior of every room; and these are multiplied by other causes, as winds of greater or less intensity blowing in through the crevices and crannies of the walls, doors, and floors, or through the spaces of open windows; and also by movement of individuals to and fro in the room; and further, by the presence of a fire, or of candles, lamps, or gas-burners. Practically, therefore, there is no rest or immobility in the air of a room; currents are always at work there; these may be in ill, and also in well ventilated rooms gentle and unobtrusive; it is only when ventilation is carried out improperly, that currents are observable and injurious.

The influence of wind acting upon a house is very considerable in creating currents through the interior of its rooms; and it is well that this should be the case, as otherwise rooms generally ill, would be worse ventilated. Where air, from the external atmosphere, is found to blow into a room through crevices, ventilation, that is a change of air, may be considered up to a certain point of efficiency, as secured; for as long as fresh or cold air be found passing into a room, some of the impure and warm air will be forced out, "for no two bodies can exist in the same space at the same time." If there are no openings at the upper part of the room by which it can escape, if there be openings at the lower part it will be forced out or pass away through them; for it is only true, as a general rule, that warmed air ascends, it can also descend; and in some modes of ventilation it is made to descend, being withdrawn from the lowest part of the room, the cold air being admitted at the highest part. The currents of air vary, in fact, very much, according to circumstances, and in practice, it will be found that they will be carried on through apertures at various heights of the room, and be both passing out from and into the interior; but, as a rule, air, in the interior of our rooms, is after being breathed so high in temperature that it ascends, and it is therefore the general practice to make openings for its escape at the upper part, and others for the admission of pure or fresh cold air at the lower part of the rooms.

We have said that the air, theoretically considered, has no movement in a confined space if the temperature is the same throughout its bulk, and also equal to that of the atmosphere external to it (*see* Fig. 8); but this in reality is not so. In accordance with the law regulating the "diffusion of gases," there is, although an unfelt, still a continual movement amongst the particles of air in spaces, the air of a room may be perfectly, mechanically, still; yet the odour of a cigar smoked, or scent exposed in one part will, in a few minutes, be diffused throughout the atmosphere of the whole room. And this diffusion takes place in all directions, and is carried on under all circumstances; and it is fortunate that it is so unvarying in its action, for it tends to diffuse gases which might otherwise be noxious, if they collected and accumulated in one spot.

We thus see that the movement of air arises from certain causes; the mechanical movement caused by winds, powerful but uncertain, by the law of diffusion of gases, and by the expansion of air under heat. It is upon the latter principle that the ventilation of our dwellings is chiefly carried out. In Fig. 9 we have illustrated the movement of air under certain circumstances, and the box in that diagram may be supposed to represent a ventilator attached to the upper part of a room, and thus be made useful in withdrawing foul or warm air from its interior. But the currents of air induced under circumstances similar to those illustrated in Fig. 9 may themselves be the means of inducing other currents, and may be used as a mechanical power, so to say, by which they may be maintained. The friction of a stream of water, projected with great velocity through a body of water, will draw with it particles of water from the surrounding body, so that it is practicable to empty a large vessel or pond of water in this way. And as with water so with air. A stream of air passing through a quiescent body of air will draw along with it particles of air from the surrounding body, and this irrespective—at least up to a certain point—of their relative temperatures, and also irrespective of their directions. Thus, if in the side of the tube or box Fig. 9, up the interior of which a current, more or less forcible, of air is passing, an aperture, as in Fig. 10, be made, the air at that point will pass from the exterior to the interior of the box, and be carried out at

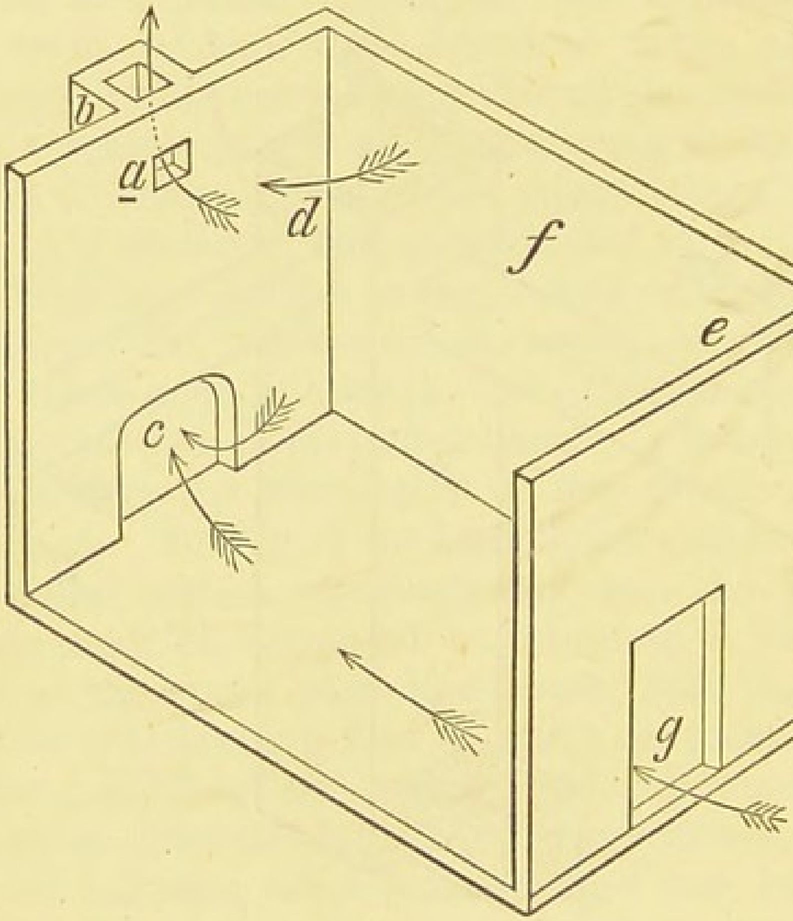
Fig. 11.



b. In the position shown at *a*, some of the current then passing through it would be due to the fact that if an aperture be made at *c*, the current from the exterior to the interior of the box will be at once established, even although the air at the point *c* may be of equal or even higher temperature than that within the box.

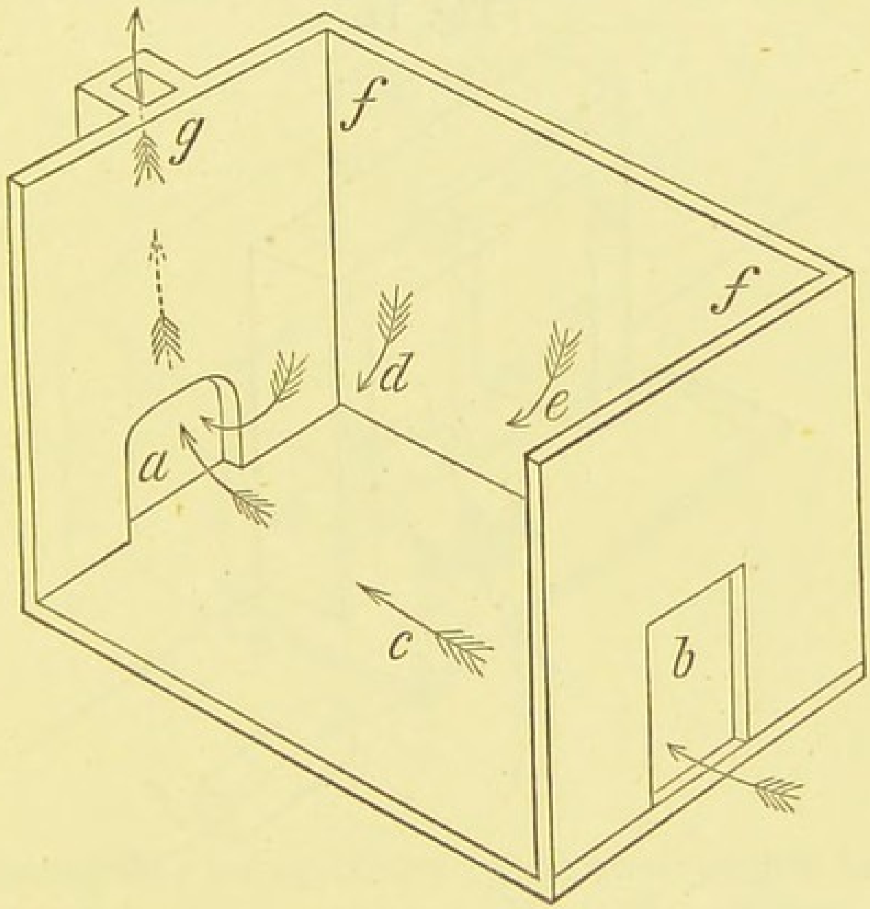
This power of establishing external currents by the aid of enclosed vertical currents of heated air—in ordinary language, by means of chimneys—is of vast service in practical ventilation. Thus, if we suppose the tube in Fig. 8 to have in place of a lamp, as at *a* in Fig. 9, a small furnace, as at *a* in Fig. 11, the current of heated air escaping therefrom at *b*, will give a power by which currents can be established, and which can draw

Fig. 12.



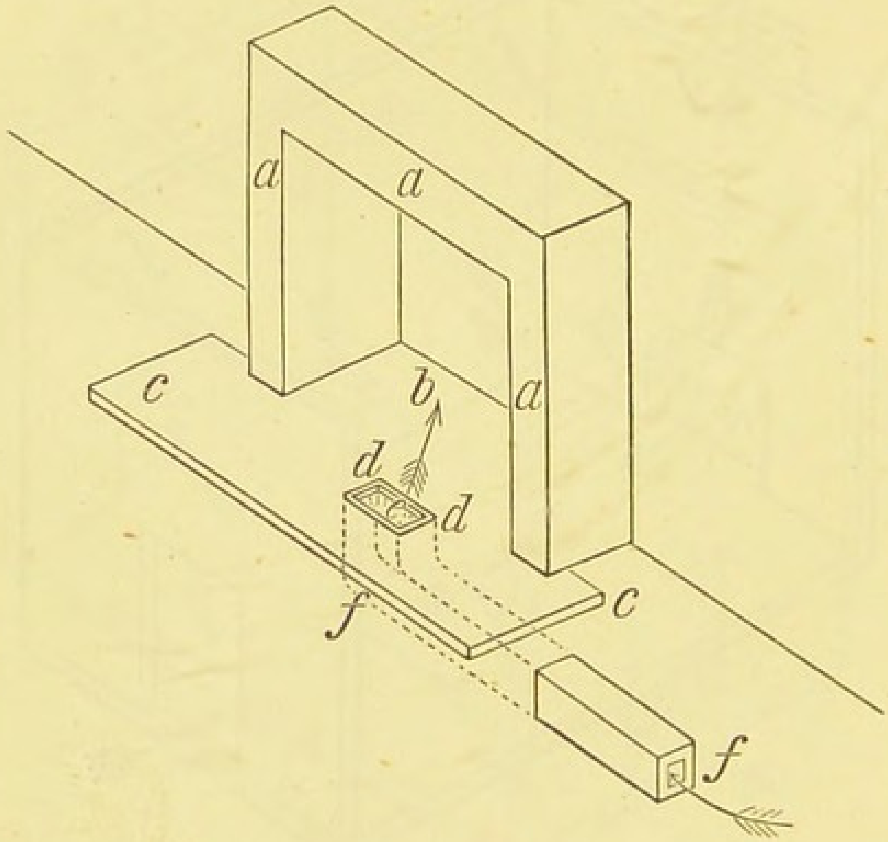
air from considerable distances, as say the vitiated air from the interior of a room placed near to, yet at some distance from, the box or chimney *b*, as, for example, by the tubes *c* and *d* communicating with the room from which the air is to be withdrawn. In Fig. 12 we illustrate how this is taken advantage of in the withdrawal of impure air from near the ceiling of a room, an opening being made at *a* in the breast of the chimney *b* of the fire-place *c*. In Fig 13, we illustrate the ordinary kind of ventilation carried on in a room in which there is a fire-place *a*. The currents are most directly drawn by this along the floor from the door *b*, as shown by the arrow *c*. The arrows *d e* indicate the currents from windows in close proximity to the fire-place, but the

Fig. 13.



air lying near the ceiling, as at *f f* and *g*, is rarely influenced by the draught of the fire-place *a*. Even when there is a ventilating opening made in the breast, as at *a* in Fig. 12, the currents thereby caused are only strong enough to withdraw air in its immediate vicinity, rarely strong enough to influence the air at a position further from it, as at *e* and *f*. In this case also the fire-place draws its chief supply from the door, as at *g*. By far the best method to prevent the currents of fresh air from passing along the room directly to the fire-place, and thus to interfere with the supply required for breathing purposes, is to introduce a special supply of cold air to the fire-place, in some such mode as we illustrate in Fig. 14, where *a* represents the fire-jambs, *b* the space occupied by the grate, and *c c* the hearth. An

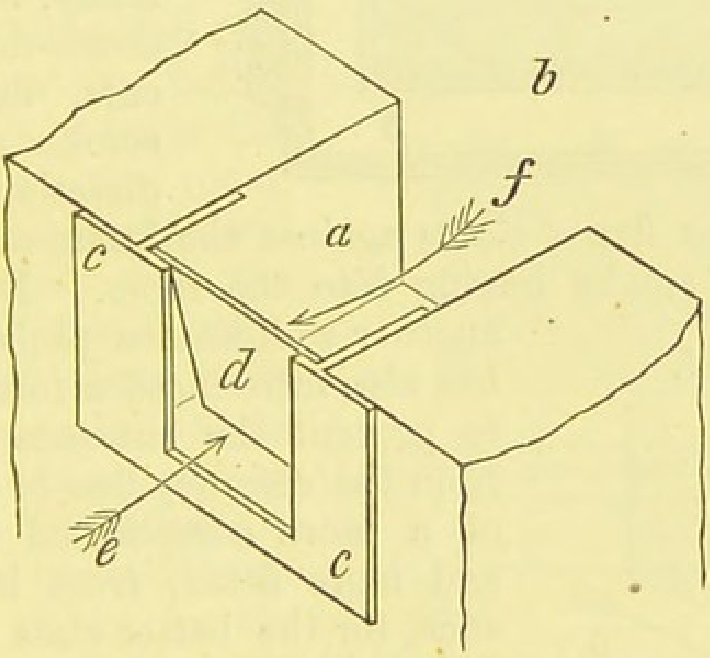
Fig. 14.



aperture (*d d*) is made in this, and supplied with a brass or iron grating, which is placed above the termination of a flue (*f f*) which communicates with the external atmosphere. If the fender covers the grating and aperture *a d d*, a few apertures may be made in the fender to admit of the fresh air entering easily to the fire-place ; the quantity of air admitted by the grating *d* may be regulated by a sliding valve provided to the grating. This method has not only the beneficial effect of getting rid of all cold, offensive draughts at or near the neighbourhood of the fire-place, but it also—and this is no small advantage—frequently, in certain cases of smoky chimneys, acts as a preventive of this most annoying fault in house construction.

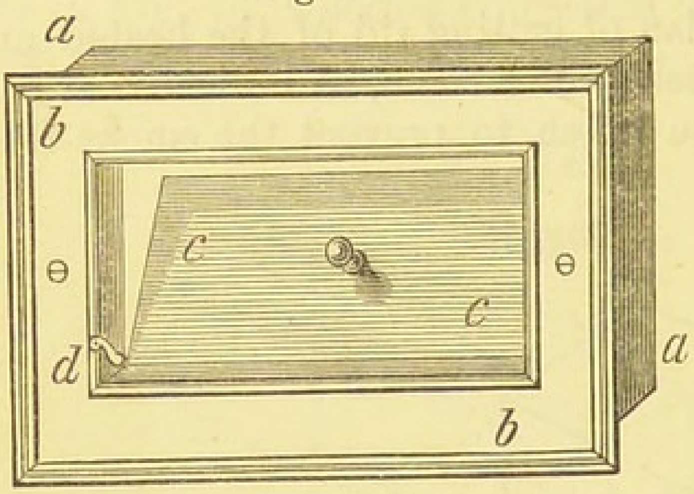
In adopting the plan of getting rid of the heated and used air from the interior of a room, as indicated at *a* in Fig. 12, care must be taken to prevent the smoke from

Fig. 15.



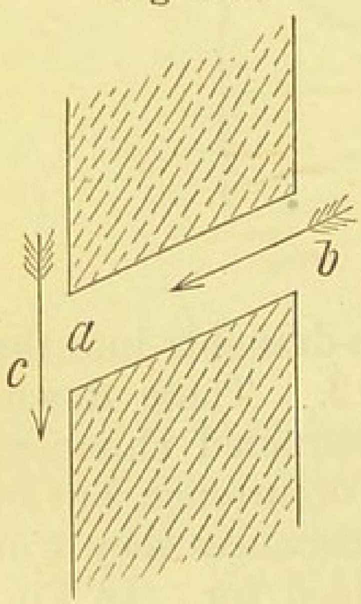
the chimney-flue being blown by down-draughts into the room through the opening *a*, Fig. 12. These down-draughts in a well designed and constructed chimney, are not, or should not be, of frequent occurrence, but in high winds, even under the best circumstances they will exist, and their effects should be provided for. In Fig. 15, we illustrate the form of valve introduced into many houses of the poorer classes by Mr Toynbee, the late well-known philanthropic surgeon of London. In front of the opening of the channel *a*, leading to the chimney flue *b*, a frame of metal, *c c*, is fixed ; to this a light flap of flexible material *d* is fixed at its upper edge, allowing the flap to act as a valve and to move to and fro freely. Under ordinary circumstances, the draught up the chimney *b*, and along the channel *a*, is such as to keep the valve open, allowing the air from the room, as indicated by the arrow *e*, to pass freely, but when a down-draught occurs, driving the smoke as in the direction of the arrow *f*, the flap *d* closes against the frame *c c*, and prevents the smoke issuing into the room.

Fig. 16.



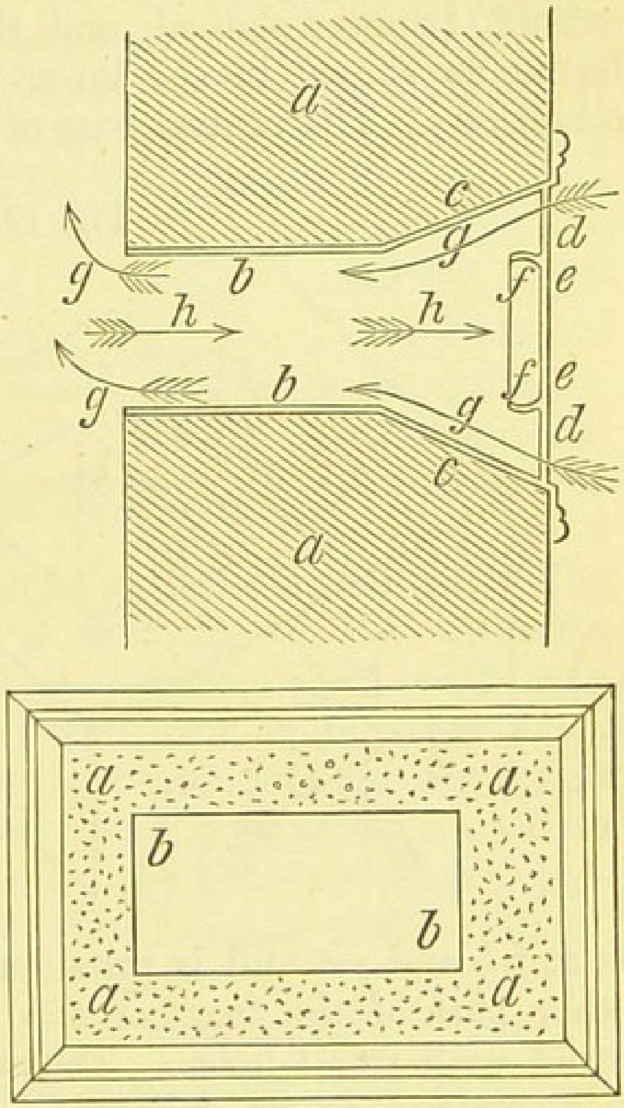
Dr Arnott, another well-known philanthropist, has also introduced a form of valve to prevent the entrance of smoke from the chimney-flue to the room, of a more complicated character, and more fitted, from its appearance, for the better class of rooms. This is illustrated in Fig. 16, where *a a* represents the metal box passed into the channel made in the chimney-breast communicating with the chimney-flue. The front of this is made of brass, as is also the moveable valve, *c c*. This is finely hung on a knife edge, and balanced by a counter-weight attached to *d*. The most delicate adjustment of balance can be secured by this. The edge of the valve *c c* plays up against a leather band fixed inside the frame so that

Fig. 17.



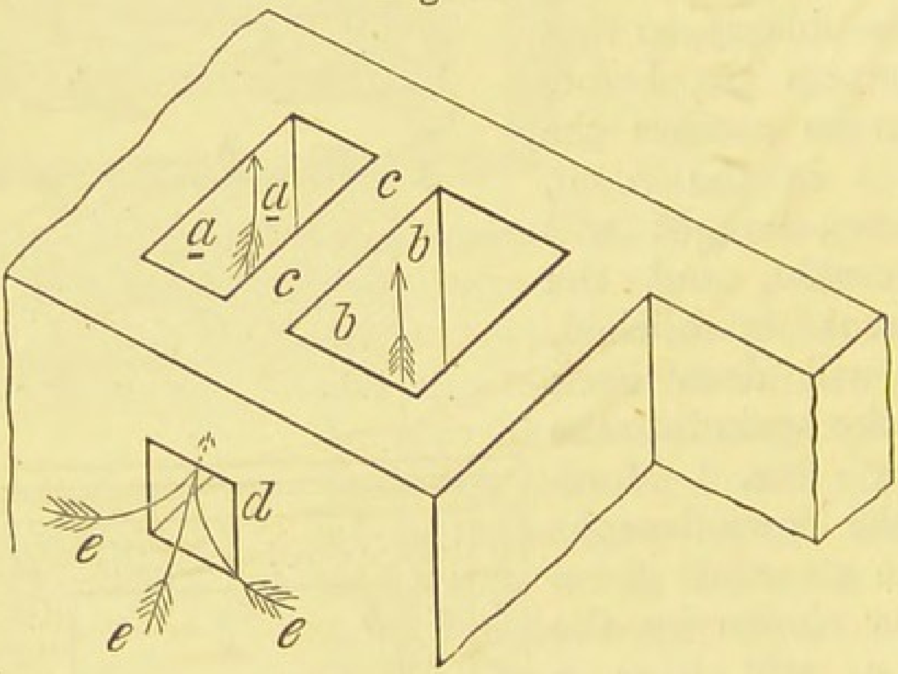
the valve makes no noise when the down-draught drives the valve up against the frame. In cases where moveable appliances, such as those described, are objected to, the simple arrangement indicated in Fig. 17 may be adopted; the channel *a a* in this case is made, not straight across the chimney-breast, as is usually the case, but in an oblique direction. The passage in which the smoke is driven back by the down-draught in the chimney is made oblique, so that the chances are, before the smoke reaches the orifice *b* in the room, the down-draught will have ceased, and the up-current established, which will draw back the smoke again into the chimney-flue. Moreover, the down-draught being in a vertical direction, as shown by the arrow *c*, will have a tendency to flow past the opening *a* rather than flow up the oblique channel *a b*. The angle of the channel should not be made too great, as then some of the smoke, under ordinary circumstances, will pass from the chimney-flue into the room along the channel. This contrivance is obviously applicable only in cases where the draught up the chimney is ordinarily good. In Fig. 18, we illustrate an appliance for openings, such as we

Fig. 18.



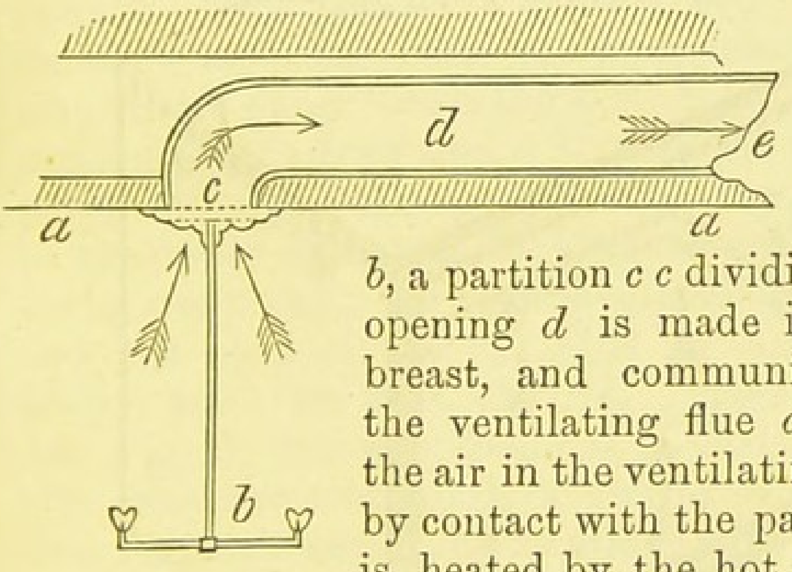
are now considering, a modification of one introduced some years ago by Mr Bryden of Edinburgh, and which may be adopted where moveable valves are objected to. In this, *a a* represents the chimney-breast, in which the channel *a b b* is cut either right across, as in the illustration, or oblique, as in Fig. 10. This is fitted with a metal box, the end of which, towards the room, is made to extend trumpet-shaped, and the opening filled with a frame, as shown in the lower drawing, which is a front elevation. The central part of this frame is made solid,

Fig. 19.



as at *b b* and *e e*, and is provided with a return *f f;* the other part of the front of the frame *d d*, *a a*, is punctured with small holes. The result, in practice, of this arrangement, is as follows:—Under ordinary circumstances, the draught of the chimney-flue draws the air from the room through the apertures *a a*, *d d*, and up the chimney, as shown by the arrows *g g;* but when a down-draught in the chimney occurs, drawing the smoke along the channel *b b* in the direction of the arrows *h h*, it is in the first place driven against the solid part *b b*, *e e*, of the frame, and part caught by the return *f f;* and by the time the smoke escapes, or is about to escape, by the apertures into the room, the upward current in the chimney is established, and the currents along the channel *b b*, in the direction *g g*, are re-established. These—or kindred—contrivances, such as now described in Figs. 15, 16, 17 and 18, are required where the channel in the chimney breast is made as illustrated, which in houses already constructed is the only mode available. But in the construction of new houses, the plan illustrated in Fig. 19 should in all cases be adopted. In this, the ventilating flue *a a* is made quite separate and distinct from the chimney flue *b b*, a partition *c c* dividing the two. The opening *d* is made in the chimney-breast, and communicates *only* with the ventilating flue *a a*. In winter, the air in the ventilating flue is warmed by contact with the partition *c c*, which is heated by the hot smoke, etc., passing up the chimney flue *b b*. The draught of the ventilating flue is thus considerably increased. In summer, a small gas jet may be made to burn in the channel *d* leading from the room. The heated air from this, passing up the ventilating flue *a a*, will increase the velocity of the current passing up it, and also of the air passing from the room by the opening *d*.

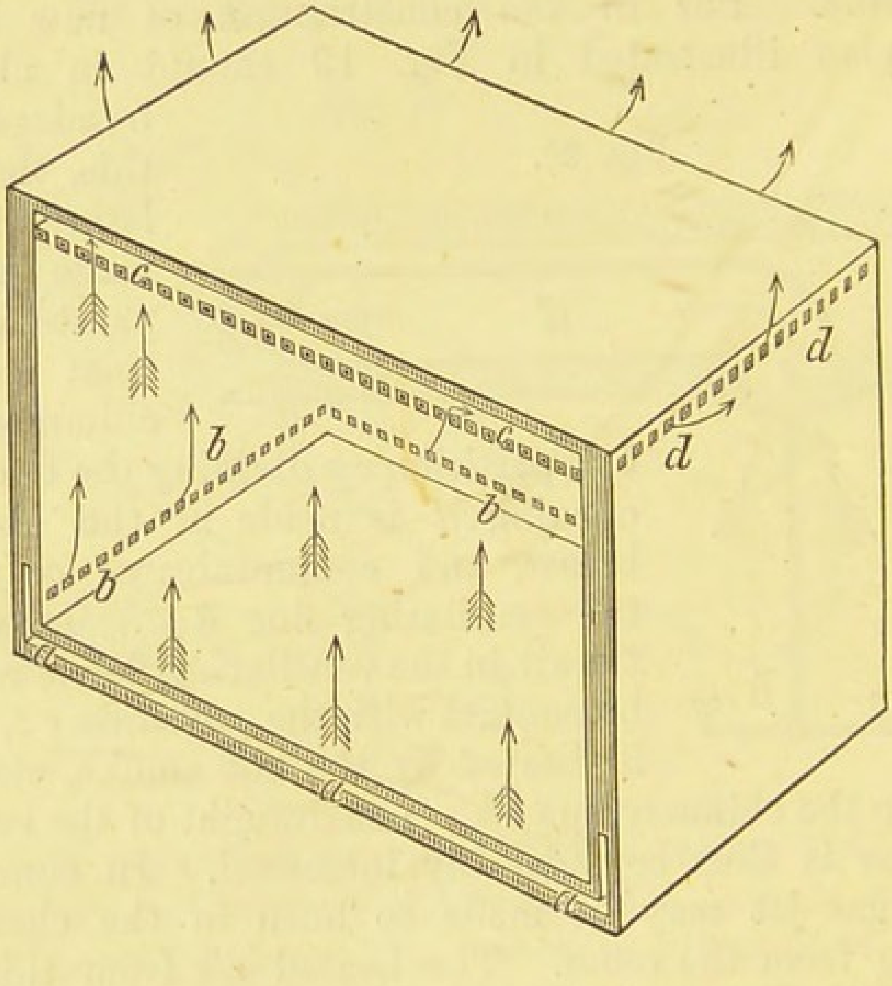
Fig. 20.



The draught of the chimney flue may also be made available for withdrawing the heated products arising from the combustion of gas in the room—one way is illustrated in Fig. 20. The hot air passing along a tube *d* above the ceiling *a a*, and communicating with the chimney-flue. From the length of the tube—the gas-lights *b* being generally placed in the centre of the room—there is little danger of the smoke from the chimney passing into the room in consequence of down-draughts.

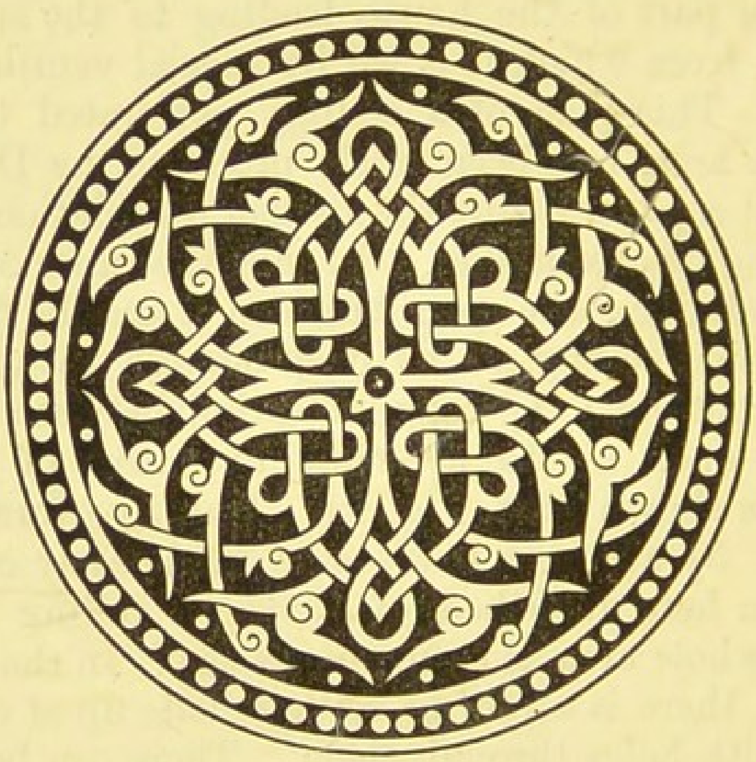
Where the arrangements for ventilating the room are complete, there will however be little necessity for having

Fig. 21.



a special arrangement made, as in the last figure, for withdrawing gas products. In Fig. 21, we illustrate a mode of ventilating a room, which would be very efficient; but which, of course, is only applicable to buildings to be constructed, as it could not—at least easily—be applied to houses already in existence. In this, fresh air—warmed by special means—hereafter in a succeeding paragraph to be described—is admitted to special channels, *a a a*, under the floor, and led to openings, *b b*, made in the skirting-board round the room. The whole area above the ceiling is hollow, as at *c c*, and the ceiling, in place of being made solid, as now universally is the case, is made up of ornamental or open-work plastering, the pattern of which gives a series of apertures, spaced equally over the surface. Through these, the heated and used air passes to the space *c*, from which it finds access to the external atmosphere by apertures *d d*, made in the walls, or led by special channels or flues to the upper part of the house, leading to the space below the roof, from which it is led by special ventilators fixed therein. This plan of a ceiling, perforated throughout its whole area, has been lately proposed by Dr Stallard, who read a paper before the British Association at Leeds, explaining its advantages. In this, the inner ceiling is of perforated zinc ; the space between it and the floor above, or the upper ceiling, to be deep enough to admit of its being swept out ; the communication between the space and the open air to be made by means of perforated bricks, as shown at *d*, Fig. 21. These perforated bricks (*see* Fig. 5) are now made at a moderately cheap rate. The plan here described, of having a ceiling perforated over its whole area, is by no means new. In the Alhambra in Spain, there is a roof or ceiling made up of ornamental bricks with holes through them. There can be no doubt that the plan will be very efficient, wherever carried out in conjunction with proper means to supply fresh air to the apartment to which such a ceiling is applied- The plan, moreover, admits of ceilings much more artistic and ornamental in character, than the dull uniformity of flat space which distinguishes those at present universally in use. Ceilings, however, would be much more artistic and certainly much more effective as aids to a good system of ventilation, if they were made coved or curved in place of flat. If so made, the necessity of having the whole area perforated might be obviated ; the perforations being made at the highest part of the ceiling only, to which the heated air would ascend. But whether flat or coved,—that is concave—a ceiling perforated throughout its whole area, could be made to form a very beautiful object in the interior of the room, in place of being, as now, what has been well named "a bald deformity." In Figs. 22, 23, we give examples of how a

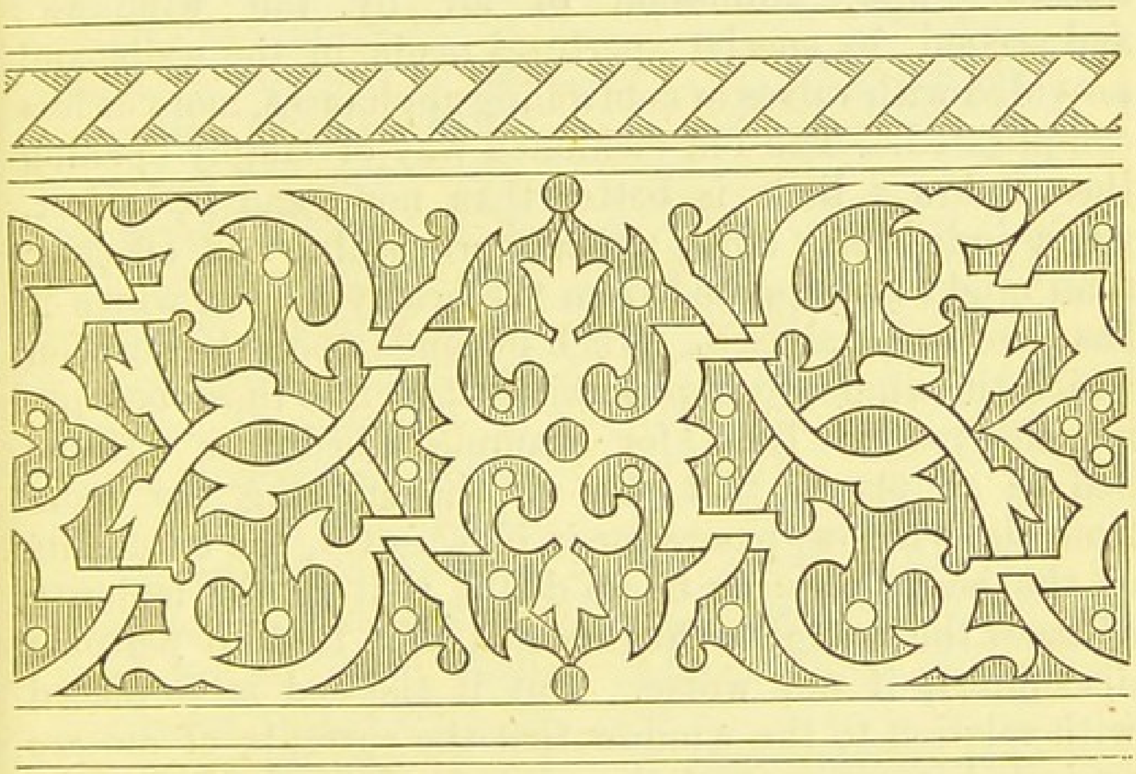
Fig. 22.



ceiling of this kind might be treated, so far as the ornamental arrangement of the perforations is concerned.

As we have already insisted upon, one essential element in all schemes of ventilation, is the supply of fresh air to take the place of that which has been used, and which is afterwards removed by openings provided. The supply of fresh air is, in houses yet to be, a much more easy matter of attainment than in houses already constructed. Special channels for its admission can be made with ease and at little cost in houses in course of construction, and the plan in Fig. 21 may be taken as indicating the chief points to be aimed at. The supply of air must be ample, and it must be of the proper temperature, to yield comfort to those who are to be placed under its influence; and it must be well diffused, not sent into the room in large volumes at only one or two places. The extended area of the skirting-boards will give ample space for numerous apertures, by which a

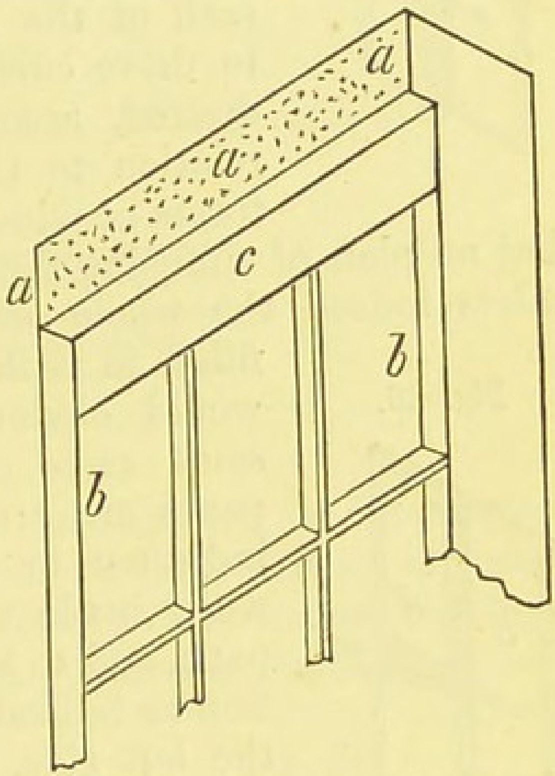
Fig. 23.



proper degree of diffusion may be secured. And to do this efficiently, and yet to please the eye, these apertures may be arranged so as to form part of the architectural design of the room. The general principle here insisted upon of having the air supplied in certain conditions, being approved of, many ways of carrying it out will suggest themselves to the reader acquainted with architectural and constructive details. In all cases, where the open fireplace is used—even although the air supplied to the room by special channels be heated by independent appliances, we would strongly insist upon the advantages to be secured by providing a special channel to supply air to the fireplace in some such way as indicated in Fig. 14.

In houses already constructed, the difficulty in the way of supplying fresh air to rooms is seldom easily overcome. The plans, indeed, which have as yet been introduced, may be said to be more of a compromise of the difficulty, rather than a complete meeting of it. They have resolved themselves, practically, into two classes — first, admission of air by the windows; and second, by special apertures made in the walls, and provided with valves or controlling appliances, more or less complicated. The old fashioned way of simply opening the window a little is better than none, and is, in fact, when judiciously done, much more useful and effective than might be supposed from the hearty way in which it has been and is abused. Much depends upon the position which the window occupies, with relation to those occupying the room. Take, for example, a bedroom. If the bed is so placed that the air, in entering the room from the window, passes, or is blown over, the occupants of the bed, there can be no doubt that in the majority of cases the draughts thus created will lead to personal discomfort, if not worse. But if the bed is so placed with relation to the window that the currents of air are projected into a part of the room far from the bed, or so that they do not pass directly over it, there also can be no doubt that the plan of supplying fresh air, and indeed of withdrawing it also, by simply opening the window, is a good one, and should be adopted without hesitation in cases where less complete and complicated plans are at disposal. No doubt the question of the night air, and its effects upon health, comes into discussion here; but if no one else has done it, Miss Nightingale has shown to our mind conclusively that the night air does not possess the noxious qualities some attribute to it. At all events, night air cannot possibly be worse in its effects upon the human system than the foul, "nauseously foul," air, which some breathe habitually every night, and all through the night. Where window ventilation is adopted, the better plan is to open the lower as well as the upper sash a little, the opening of the upper sash to be in excess of that of the lower sash, to admit of the freer exit of the larger volume of heated and used air. The worst feature connected with window ventilation is the way in which the currents of air are passed into the room in large volumes without being diffused. The best way to secure the necessary diffusion is to have a narrow frame fixed permanently outside in which perforated zinc is fixed. This will be no disfigurement to the window, as it does not require to be more than five or six inches wide, as shown in Fig. 24 at *a a*. In this diagram, the upper sash *b b*, is supposed to be lowered, and when raised or closed, the part *c* will nearly, if not altogether, hide the zinc *a a*. The same provision should be made at the lower sash outside, unless perforated under-blinds be there used, when they will answer the purpose of air diffusers. Another disadvantage connected with the sash window as a ventilator is that the currents of air pass always into the room in one direction—that is,

Fig. 24.



straight from, or at right angles to, the window. This disadvantage is obviated by the use of the French or casement window, illustrated in Fig. 25, which admits of one sash being opened according as it is desired to change the direction of the current of air from right to left, or *vice versa*. Thus, if it is desired to drive the current of air to the side *a*, the sash *b* is opened while that marked *a* is kept closed. By dividing the window into four, as in Fig. 26, it is obvious that each of the four divisions may be used to drive currents of air in any direction desired, according as it is opened with relation to the others. But these two forms of window have this disadvantage, that no plan of diffusing the air can be applied to them, unless indeed the whole area of window outside was filled in with a perforated frame, which would obviously be inadmissible. In some cases of window ventilation, the panes are provided with perforations, as indicated in Fig. 27. These are best when made to stretch nearly across the pane, and to be made in an oblique direction as indicated at *a b* in the drawing to the left side, the air being thus thrown upwards to the ceiling, where it mixes with the warm air. If the shutters are closed at night, apertures should be made in the shutters opposite to those made in the panes of glass.

Fig. 25.

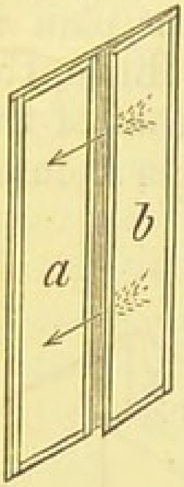
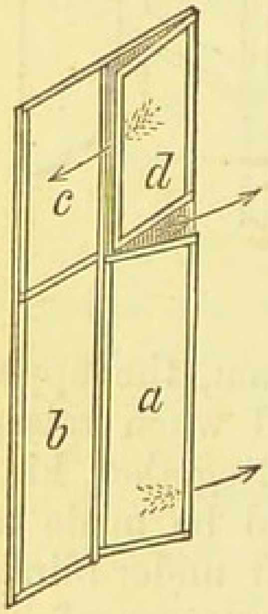


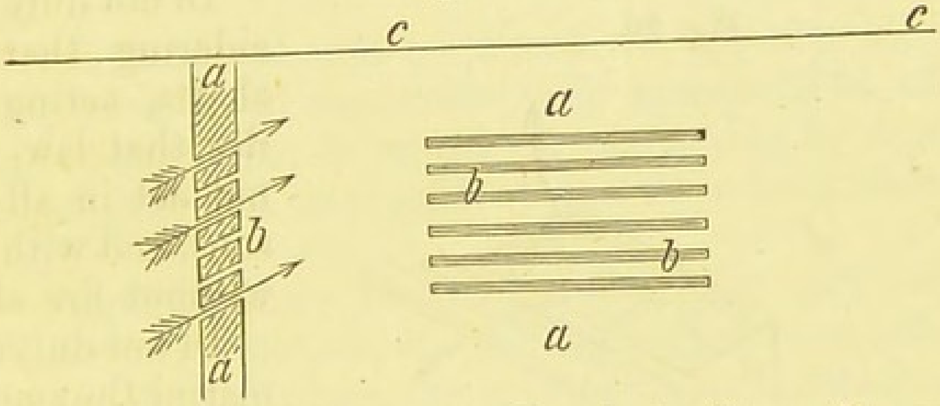
Fig. 26.



In view of the decided advantages to be obtained from ventilating by means of the window—with all its faults infinitely better than no ventilation at all—and so long as special and more complete appliances are wanting; and in view, moreover, of the dislike which many have to fresh air, it has been proposed to keep permanently open at least one window of every house at the top some three or four inches, and securing it fast, so that the opening cannot be closed. If this be done, and we are inclined strongly to recommend the doing of it, a perforated zinc diffusing plate, as in Fig. 24, should be applied to the opening.

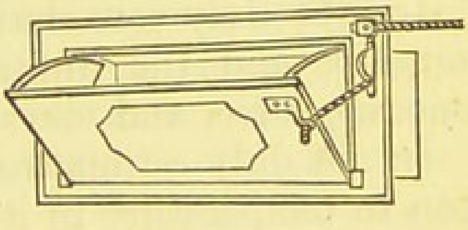
We now describe briefly the second method in use for admitting fresh air to apartments already constructed—namely, by simple apertures in the wall, provided with

Fig. 27.



means by which the air can be shut off, or its current regulated as desired. The best of these valves—at least the one most largely used—is that known as Sheringham's, illustrated in Fig. 28. Another method of admitting fresh air to the interior of a room, and which has been adopted in some of Her Majesty's barracks, is illustrated in Fig. 29. In this the cornice *a a* is made at intervals hollow, and the upper part of the space thus formed is covered with a frame filled in with perforated zinc. The space communicates with the external air by means of a channel cut in the wall as at *d d*.

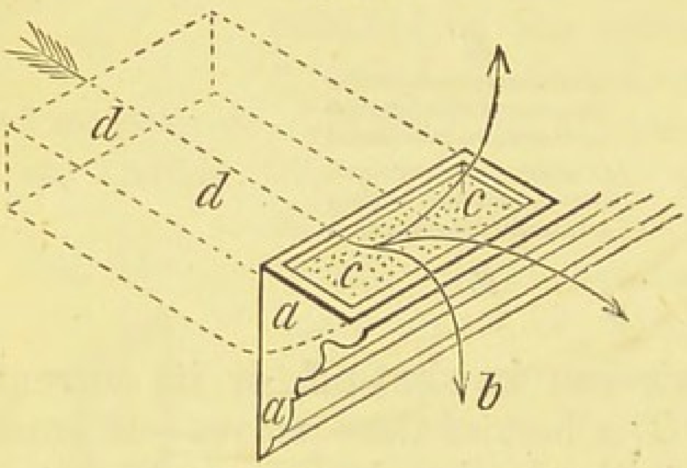
Fig. 28.



In concluding our remarks upon the principles upon which ventilation depends, and the means by which they are carried out, we deem it right to give here a place to a few of the leading conclusions come to on the whole subject by Dr Edwards, who has had extended official experience in connection with its practice, and who recently read a paper on ventilation before the Society of Arts. The errors, according to Dr Edwards, made in ventilating, are—

In not duly estimating the practical limits of the law, that heated air ascends, and the relation of numbers of inmates and size of rooms in the application of the law.

Fig. 29.



In not duly considering that air shafts, acting under that law, cannot act in all seasons, and with and without fire alike.

In not duly estimating the amount of air which can be admitted by windows and doors alone. In not duly estimating the practical limits to which an entering current may be carried, whether from one or both sides of a room.

In not duly considering the effects of currents upon inmates, and the limitation thus demanded upon the amount, force, and elevation of currents.

In not duly estimating the inverse relation of ventilation to temperature in its effects upon inmates, and particularly upon the old and the young.

In not duly estimating the influence of the winds, and the impediments of surrounding buildings, &c., upon each aspect of a building.

in having incorrect views as to the direction of the current through ventilators at different elevations.

The following are the chief conclusions come to by Dr Edwards on the subject of ventilation :—

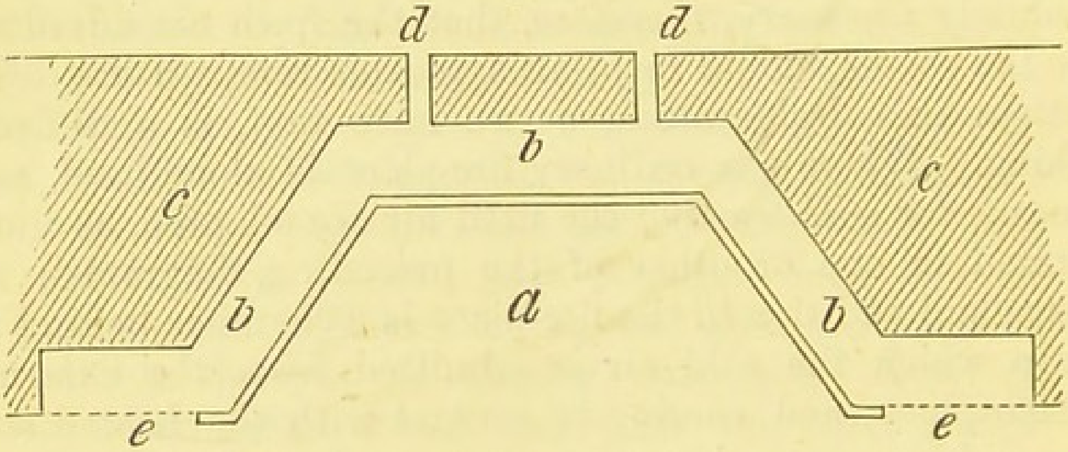
"Each room should be so constructed that its ventilation may be independent of that of staircases or any other room; but where two rooms are placed side by side, with a partition wall between them, each having windows on one side only, the ventilation of each is improved in proportion as a part of the partition wall is removed. Thus one room may improve the ventilation of the other, and both be as if they had windows or ventilators on both sides.

"Ventilators should be placed on opposite sides of a room, be of small size, sufficiently numerous to affect all parts of the room, defended on the inside by finely-perforated zinc, and be placed at the floor level and ceiling level.

"Ventilators in a small part of a room only are insufficient for ventilation, since when a current of air passes between two openings, the greater portion goes in a direct line, and does not greatly mix with the air on either side of it. This may be readily seen when smoke is admitted by an inlet, and emitted by an outlet ventilator, or such an arrangement as exists in prison cells."

In the preceding observations which we have made upon ventilation, we have specially referred to one of the difficulties connected with it—that is, the supply of fresh air *at a proper temperature.* It is comparatively easy to admit fresh air, cold, or at the temperature of the external atmosphere, in any desired quantity to the interior of an inhabited room ; but it is not so easy, rather, it is very difficult, to have the temperature of that air at such a point that it will be felt to be agreeable to those with whom it comes in contact. The difficulty is greater, no doubt, in winter than in summer, when the supply of air to a room is colder than that which is the normal temperature in its interior; but the difficulty by no means vanishes in the summer ventilation of rooms. Nearly all have a great objection to the influx of cold air into a room in such volumes, and in such a way, that draughts are created or are supposed to exist. Whether the view popularly taken as to the danger arising from the passage of air through ventilating openings be right or wrong, the fact exists that the majority of people hold it, and ventilation, therefore, is an eminently unpopular thing. We say this advisedly, notwithstanding the great outcry there is as to its importance to health, for in practice we have rarely found ventilating plans carried out, without incurring the censure of the very parties who declaimed most loudly as to their absolute necessity. Ventilation is admitted by all to be a good thing, but they are few indeed who do not object to the admission of air to rooms, as if ventilation could be secured without it. And even where the openings for its admission have been so carefully planned and arranged that the air has been so well diffused as to be admitted without any sensible draught or current, the plans have all the same been condemned, and with no other reason than this, that where there are openings there must be draughts. They may even admit that the draughts are not felt, but the conclusion is come to nevertheless that they must be there, and being there must be dangerous. But it may be said, that all this is very unreasonable, and should not be attended to or allowed to influence the carrying out of plans for ventilating the rooms in which men live, but the misfortune of the thing is, that those who do so object, however unreasonably, have so much in their power that they may make all plans inoperative. This is specially true of the working, and very specially so of the lower classes, who have a remarkable dislike to fresh air being admitted to their rooms, especially if that air be colder than the general atmosphere of the room, and as this must always be the case, the practical result is, that as a rule all ventilating appliances are rendered inoperative by a number of ways familiar to those who are acquainted with the usual phases of sanitary reform. Seeing all this, and however much we may deplore it, we must not lose sight of this, that it is a fact which has in future to be dealt with; and that moreover there is the truthful side of the prejudice; for there is no doubt of this, that while, to our mind, it is better to breathe cold air than foul warm air, in such a climate as ours cold air does give a feeling of discomfort to those with whom it comes in contact. To make plans of ventilation *popularly acceptable*, it is absolutely necessary, therefore, that the fresh air admitted to the rooms should be of an agreeable temperature. To attain this desideratum, as we have said, is a difficult thing. Where the ordinary fire-place is alone used, and means for *withdrawing* the used air are adopted, as illustrated in one or other of the preceding diagrams; an excellent addition to the fire-place is a chamber behind it, into which the cold air is admitted from the external atmosphere, and coming in contact with the heated surface of the grate, becomes warm, and is then admitted to the room by apertures in the skirting board, or the upper part of the cornice of the wall at each side of the fire-place. Or, if its entrance to the room at these points be objected to, it may be led by special channels to any desired part of the room. This arrangement is illustrated in Fig. 30, in which *a* represents the position of the grate, *b b* the space behind it, made in the wall, *c c*, in which also are channels, *d d*, communicating with the external atmosphere. The apertures for admitting the warmed air to the room are at *e e*. There is no better plan than this for utilising the heat, otherwise lost, of the common open fire-place, and of supplying fresh air for breathing purposes, but at an agreeable temperature. The plan is a very old one, having been brought forward by Cardinal Polignac early in the sixteenth century, and illustrated in a variety of adaptations, in a book to which he appended the *nom de plume* of " Gauger." Very freely have the contents of this work, now very scarce, been availed of by a number of inventors and patentees since the date of its publication, and few of them have acknowledged the source of their inspiration. No doubt, modern appliances and modern workmanship, in the hands of modern inventors, have had their effect in bringing out ventilating fire-places of more handsome design, and per-

Fig. 30.



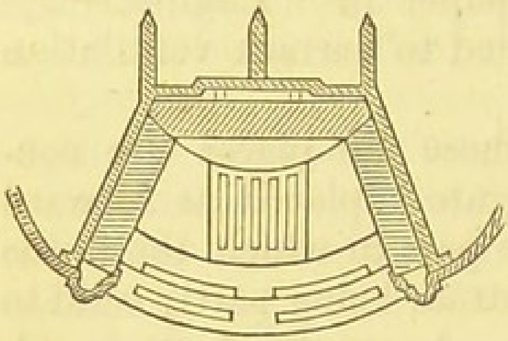
haps more efficient arrangements, than those first shown by the Cardinal in his work above referred to, but all are upon the same plan as that which he explained.

The most recently introduced, and undoubtedly the best, ventilating fire-place upon this principle, is that of Captain Galton, R.E. The plan of warming and ventilating apartments, introduced by this gentleman is, however, marked by some features peculiar to it, which are obviously the result of no small study and observation on the subject. The most careful experiments have been made with this apparatus, all of which have established the fact, that it appears to be unsurpassed as a ventilating and warming appliance where the pleasures attendant upon an open fire-place are desiderated essentials. Captain Galton read a paper recently before the Society of Arts and the British Association, from which we take the following statements, preceding it with illustrations and description taken from a paper in "Engineering," descriptive of the plan as applied to barrack ventilation and warming :

"The principles on which these fire-places are constructed are as follows :—The grate is placed as forward as possible into the room. The part in which the fire is contained is of fire-brick, the bottom being partly solid to check the consumption of fuel. A supply of air is admitted from behind the grate, and thrown upon the top of the fire to assist in preventing smoke. The sides are splayed, so as to throw the heat, by radiation, as much as possible into the room ; the opening into the chimney has no register. A chamber is placed behind the grate, into which air is brought from the outer atmosphere, and warmed by the large heating furnace of the back of the grate, increased by flanges, and after being heated to a temperature of from 56 deg. to 70 deg. Fahr., the air passes into the room by a shaft cut out of the wall, which terminates in a louvred opening above the reach of the men. The accompanying sketches will show the mode in which these principles have been carried out. Figs. 31, 32, and 33, are a plan, elevation, and section of the stove ; the fire lump-lining of the grate, as shown by the parts *b* and *c*, are shaded. The back lump has groves in it, terminating in holes just at the bottom of the splay, which forms channels for admitting air at the back over the fire. The hearth is formed of a plate of cast iron. These grates are made in three sizes, and fixed to suit the cubical contents of the rooms. Thus, a grate, with a fire opening of 1 ft. 3 in., is fixed in rooms not having more than 3600 cubic feet of contents. A grate, with 1 ft.

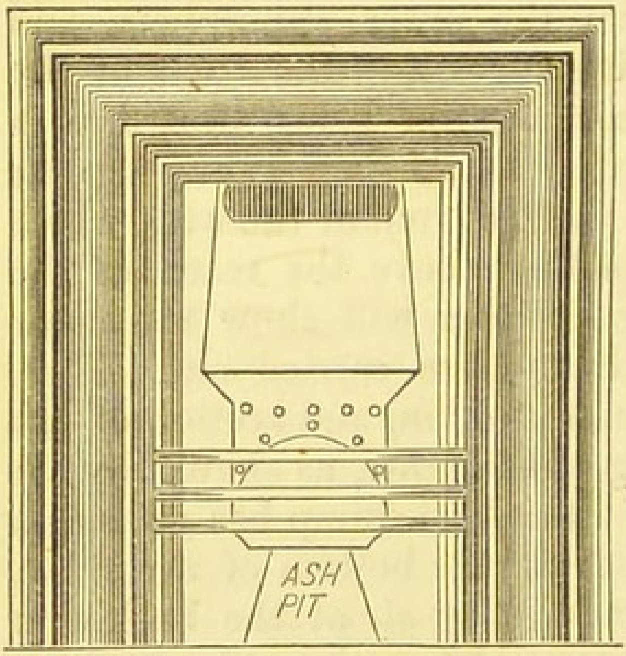
5 in. opening, is used in rooms having from 3600 to 7800 cubic feet of space, and the largest size, having a 1 ft. 9 in. opening, is for rooms having from 7800 to 12,000 cubic feet of space. The plan further shows the dimensions of the ordinary opening for the fire-place of a barrack room, with the method of setting the stove and forming the air chamber.

Fig. 31.



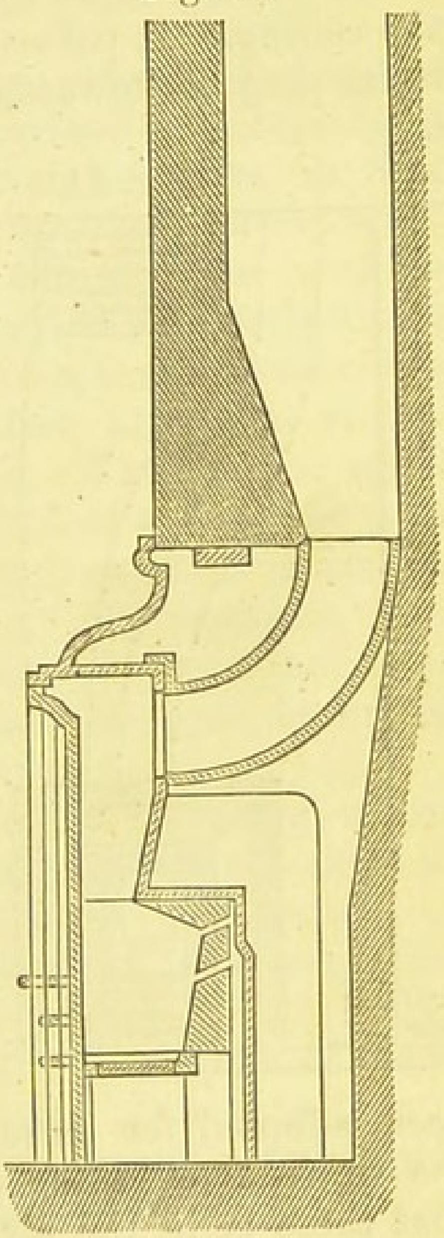
"From the air chamber at the back of the fire-place the air is conducted into the room by a shaft shown in the elevation Fig. 34, and through a louvred opening, placed as near the ceiling as possible; the clear area through the louvres being made much larger than the area of the shaft, the louvres being bevelled upwards so as to cause the air to impinge against the ceiling to prevent a cold draught being felt when the fire is not lighted, and fixed by means of screws so as to be easily removable for the purpose of cleansing. The air shaft is formed in brick-work, and should be rendered inside with Portland cement, and then lime whited. The minimum area of the shaft is one square inch to every 100 cubic feet of room space. Where it was inconvenient to break into the chimney breast, the air from the chamber in which it is warmed is admitted to the

Fig. 32.



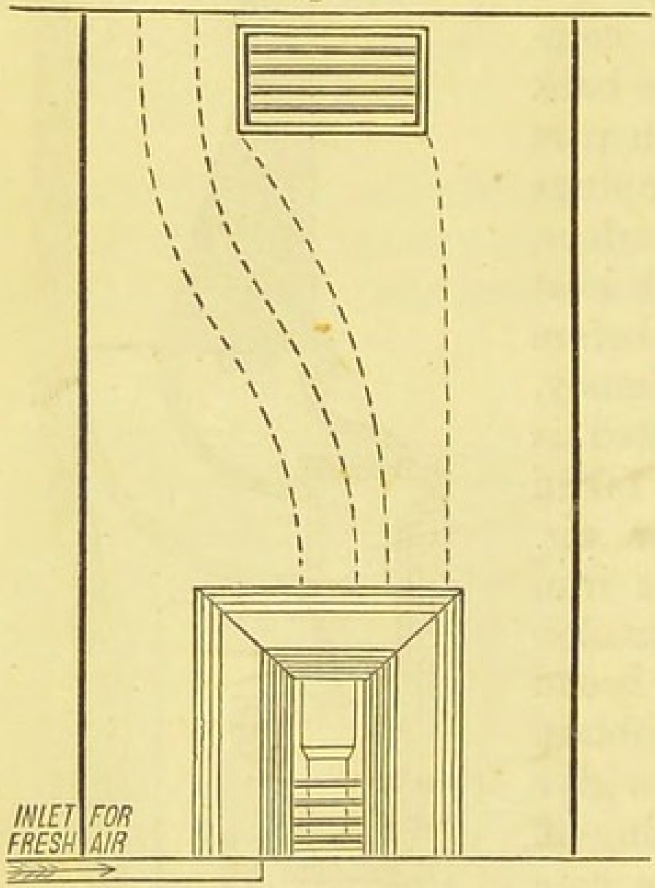
room through a shaft of sheet iron fixed to the wall, the top being sloped back and covered with perforated zinc. The shaft communicates with the chamber behind the fire by a hole in the top of the front projecting part of the stove."

Fig. 33.



"The flame," says Captain Douglas Galton, in his paper read before the British Association, "heated gases from combustion, and such small amount of smoke as exists, are compelled, by the form of the back of the grate and the iron part of the smoke flue, to impinge upon a large heating surface, so as to subtract as much heat as possible out of them before they pass into the chimney, and the heat thus extracted is employed to warm air taken directly from the outer air. This air is warmed by the iron back of the stove and smoke-flue, upon both of which broad flanges are cast, so as to obtain a large surface of metal to give off the heat. This giving-off surface (amounting in the case of No. 1 grate to 13·5 square feet) is sufficient to prevent the fire in the grate from ever rendering the back so hot as to burn the air it is employed to heat. The fresh air, after it has been warmed, is passed into the room near the ceiling. In a room furnished with an ordinary open fire-place with closed doors and windows, the experiments made by Mr Campbell for the Board of Health in 1857 showed that the circulation of air proceeds as follows: The air is drawn along the floor towards the grate, it is then warmed by the radiating heat of the fire, and part is carried up the chimney with the smoke, whilst the remainder flows upwards near the chimney breast to the ceiling. It passes along the ceiling, and as it cools in its progress towards the opposite wall, descends to the floor to be again drawn towards the fire-place. It follows from this that the best position in which to deliver the fresh warm air required to take the place of that which has passed up the chimney, is at some convenient point in the chimney breast, between the chimney-piece and the top of the room, for the air thus falls consequently into the current and mixes with the air of the room without perceptible disturbance.

Fig. 34.



"The flue which has been adopted for barracks is carried up by the side of the smoke-flue in the chimney-breast. It will be seen that there is in the air chamber of No. 1 grate a heating surface for warming the air of about 13·5 square feet. The area of the grate is 84 square inches, of which 58 in. are solid, and 26 afford space in the centre for the passing of air. The front is open, and air is passed on to the coal from the back in the manner already described. The grate will contain about 18 to 20 lb. of coal; when the fire is maintained for from twelve to fifteen hours, a total consumption of about 2·5 lb. per hour, or 40 lb. for sixteen hours, will suffice to maintain a good fire. For soldiers' rooms the daily allowance in winter with No. 1 grate is nearly 46 lb. per diem.

"In new buildings it would be possible, and indeed desirable, to extend this heating surface considerably by carrying up the smoke flue inside the warm air flue. This plan has been adopted in the fireplaces for the wards of the Herbert Hospital, where the fireplace is in the centre of the ward, and the chimney consequently passes under the floor; and by this means a heating surface for the fresh air, of above 36 square feet additional to that of each fireplace, has been obtained. The limit to which the heat from the fire can be so utilised will be the point at which it cools down the chimney, so as to check the draught and combustion of the fuel. With respect to the application of the grate to existing buildings, the recess in which an ordinary firegrate would be fixed, forms the chamber in which the air is warmed.

"In order to afford facilities for the occasional cleansing of this chamber, and those parts of the air channels connected with it, the front of the stove is secured by screws, so that it can be easily removed, thus rendering the air chamber accessible.

"The stove was designed with the object of being applied to existing chimney openings. In so applying it, the air chamber is to be left as large as possible, thoroughly cleansed from all old soot, and rendered clean with cement, and lime-whited. Should the fireplace be deeper than 1 ft. 6 in., which is the depth required for the curved iron smoke flue, then a lining of brickwork is to be built up at the back to reduce it to that dimension. The chimney bars, if too high, must be lowered to suit the height of the stove, or to a height above the hearth of 3 ft. 3 in. ; they must also be straightened to receive the covering of the air chambers. These coverings should be of 3 in. York or other flagging, cut out to receive the curved iron smoke flue, and also to form the bottom of the warm air flue in the chimney breast. In new buildings the air chambers may be rectangular ; they must be 4 in. narrower than the extreme dimensions of the moulded frame of the stove, so as to give a margin of 2 inches in width all round for a bedding of hair mortar.

"Numerous experiments have been made at different times upon these grates, both as regards the quantity of air supplied and the temperature maintained. The general results show that the air is admitted into the rooms at a temperature of from 20 to 30 deg. Fahr. above that of the outer air. The design of the grate was intended to preclude the possibility of such a temperature as would in any way injure the air introduced ; and the following table of some experiments made by Dr Parkes in an hospital ward at Chatham, illustrates the hygrometric effect with the grate in use :

TABLE I.

DATE.	External Air. Mean of three Observations Daily.				Air in Ward. Mean of seven Observations Daily.			
	Dry bulb.	Wet bulb.	Difference.	Humidity. Saturation=100.	Dry bulb.	Wet bulb.	Difference.	Humidity. Saturation=100.
	Deg.	Deg.	Deg.		Deg.	Deg.	Deg.	
April 17 .	50·0	43·5	6·5	60	58.0	50·6	8·0	60
,, 18 .	51·5	47·0	4·5	72	56·6	51·2	5·0	71
,, 19 .	54·0	50·0	4·0	74	59·6	54 7	4·9	71
,, 20 .	54·0	51·5	2 5	83	59·1	54·2	4·9	71
,, 21 .	54·6	51·5	3·1	80	59·6	54·3	5·3	71

"The greatest difference between the dry and wet bulbs in the ward was :—

On the 17th, ...	8·5 Deg.
,, 19th, ...	5·5 ,,
,, 18th, ...	6·0 ,,
,, 20th, ...	6·5 ,,
,, 21st, ...	5·0 ,,

"On examining the record of the dry and wet bulbs during these days, no evidence can be seen at any time of any unusual or improper dryness of the atmosphere. The difference between the two bulbs was certainly always greater in the ward, but it was not material.

"The temperature of the rooms was invariably found to be so equable that when the grate was in full action, and the windows and other means of ventilation closed, thermometers placed in different parts of the room, near the ceiling and floor, in corners furthest from the fire, and on the side nearest to it, but sheltered from the radiating effect of the fire, did not vary more than about 1° Fahr. The variation of temperature in a room warmed by a fire by radiation, without the action of warmed air, will be found to be from 4° to 6° Fahr., and sometimes even more in cold weather."

The temperature of the air in different buildings, where ventilation is so well arranged, that the removal of the air is continual, may with safety be so regulated as to be higher than when the change of air is not continuous, or not attended to, as in the majority of present buildings. General Morin, the French *savan,* who possibly has done more than any other man in putting the subject of ventilation and warming of public buildings upon a scientifically accurate footing, recommends the following temperatures for different buildings :

Hospitals, ...	61° to 64° Fahr.
Workshops, Barracks and Prisons, .	59° ,,
Schools, ...	66° ,, 68° ,,
Meeting Rooms, ...	66° ,, 72° ,,
Theatres, ...	68° ,, 72° ,,

The temperature of the fresh air to be introduced into the room or place to be warmed and ventilated, should be the same as that at which the air of the room is desired usually to be. But this is subject to modifications in practice, as for example where there are many and large windows in a room, the glass surfaces of which brings down the temperature very much. In such cases, the temperature of the air sent into the room will require to be much higher—from 85° to 95° Fahr. On the other hand, should the building to be ventilated be crowded or well filled, or if a number of artificial lights be placed in the interior, then the temperature of the air sent into the interior will require to be lower. In large buildings, as churches, schools, etc., it will be well to provide a chamber into which the warmed air from the heating apparatus should be passed, in which cold air can be mixed with it before the volume of fresh air is passed into the building. General Morin has shown the relations which exist between the volume and the temperature of the air, and the areas of the flues or shafts by which the air is withdrawn from the building. These we now give, preceding them with the formulæ:

$$V = C \sqrt{(T - T') H}$$

$$Q = CA \sqrt{(T - T') H}$$

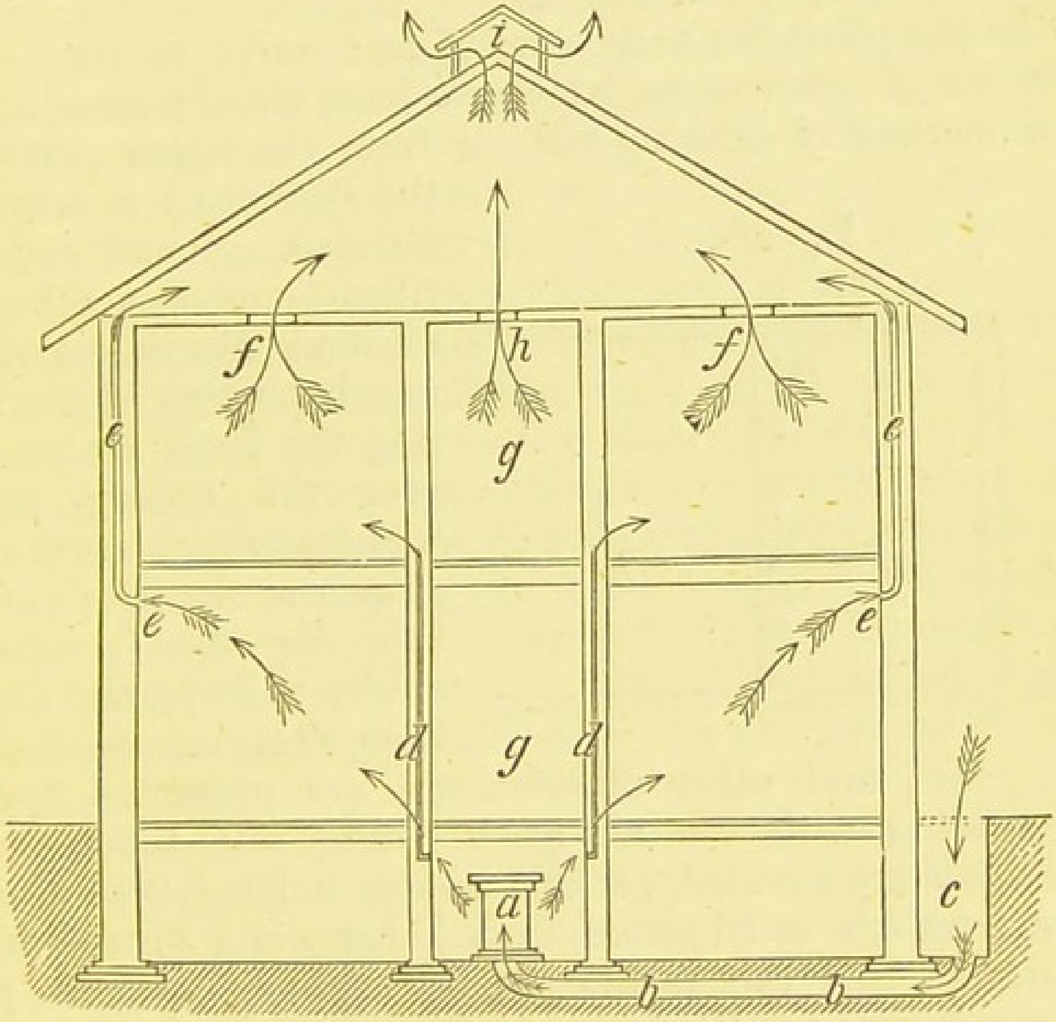
In which A is the sectional area of the flue or shaft for exit of the air,
H ,, height of ditto,
T ,, average temperature in ditto,
T′ ,, temperature of external air,
C ,, co-efficient, constant for each flue as regards its proportions,
V ,, average velocity of the air in the flue,
Q ,, volume of air passed along the flue in a second.

" The results derived from these relations are that the velocity of the escaping current is proportional to the square root of the excess of the temperature of the heated air in the flue over the external air, and also to the square root of the height of the flue or chimney; and the volume of air extracted is consequently proportional in addition to the sectional area of the flue."

M. Morin states that the velocity of the air should continually increase as it progresses along the flues from its entrance to its exit—the exit being a single shaft, into which all the separate channels lead. The velocity at the entrance in feet per second should be from 2·3 to 2·9 feet; in the first channel from 3·3 to 3·9 feet per second, in the second channel from 4·3 to 4·6 feet, and in the discharging or final shaft from 5·9 to 6·6 feet per second. These velocities will be maintained with pretty fair accuracy, if the temperature in the discharging shaft be from 70° to 80° Fahr. in excess of the temperature of the external atmosphere. This should be the temperature in ordinary buildings; but in theatres and crowded buildings, and where the air channels are numerous and complicated, an excess of temperature in the discharging shaft of from 95° to 105° over that of the external atmosphere will be required. When the warm, fresh air is introduced at openings in the ceiling, the velocity of the current which will thus descend upon the heads of those in the room should not exceed 1·6 feet per second; but should it be supplied at the sides of the room at a considerable height, the velocity may be as high as 3·3 feet per second.

An excellent method of keeping up the temperature of the house apartments generally, is to have a stove in the lobby or hall. There are now many excellent forms of stoves introduced for this purpose, some of which we afterwards illustrate: The worst feature of the majority of stoves is, that they dry the air too much; and air thus deprived of its natural moisture exercises a prejudicial effect on the system. Hence the necessity that exists for restoring the moisture to air which has been deprived of it by coming in contact with the over-heated surfaces of stoves. This is easiest done by having an open dish of water placed upon the stove—the evaporation from which gives humidity to the atmosphere. An excess of this should be avoided. Air at 56° is "saturated"—that is, contains as much water as will be suspended in it without dropping—when it contains five grains to the cubic foot, and seven grains to the cubic foot at 66° Fahr. When accuracy as to the degree of moisture in the air is required, a hygrometer should be used, in addition to the thermometer, and a pleasant, healthy degree of humidity will be attained when the humidity is about 60°, complete saturation being indicated at 100°, or with the thermometer at 50° or 60°, the hygrometer shows 45° and 54°, or dew-points 40° and 49°. General Morin dispenses with the necessity of moistening the air by adopting the plan of heating a small portion of the air only, mixing this with a quantity of cold air. By this means the mixture contains a sufficient degree of moisture. When the whole supply of fresh air is warmed, it is necessary to moisten the air by some means, such as we have above indicated. The smaller the number of people assembled in a room, the greater necessity is there to moisten the heated air, as the moisture exhaled in respiration will not be enough to moisten the air; and this moisture, as we have already said, is not a healthy source from which to moisten the warm air supplied to a room. In a building densely-crowded, there is too much moisture, as a rule. If a dwelling-house be supplied with cellars, as in Fig. 35, the stove or heating apparatus may be put in one of the cellar rooms, as *a*, this being supplied with cold air by a channel *b b*, drawing from the well-hole *c*. The hot air from the chamber *a* may be made to pass to the various channels *d d*, each room having a separate channel. The used air may be withdrawn from the lower rooms by flues *e e*, such as we have already described, opening into the space below the roof, as shown; the used air from the upper rooms by openings in the ceiling, as *f f*—the staircase *g g* being ventilated by the same means as at *h*. If there are no

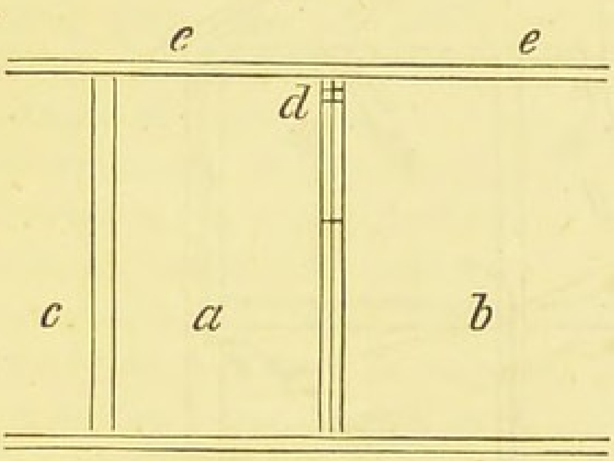
Fig. 35.



cellars in the house, the stove may be placed in the lobby, and the warm air supplied as described at the beginning of this paragraph. If closets are used as sleeping places (*see* our remarks on such in Chapter II.), special arrangements should, in all cases, be made to withdraw the foul air from their interior. The door *a*, Fig. 36, opening into the larger apartment *b*, or the lobby *c*, as the case may be, may supply fresh air, but it cannot act effectually as a means for withdrawing the foul air from the closet. The only way to secure this withdrawal, is to have an opening into the larger room *b*, or lobby *c*, both of which should be carefully ventilated, or the ceiling may be provided with apertures leading to an air channel *e e*, communicating with the ventilating flue provided for the large chamber *b*, or lobby *c*.

In the plans for withdrawing used warm air from the interior of apartments, which we have already described, the method of drawing the air from the upper part of the apartment is recommended. Some authorities—amongst others, General Morin—recommend the plan of admitting the fresh air at or near the ceiling, and withdrawing the foul air at or near the floor; and this for these reasons chiefly; first, all dust from sweeping the floor, etc., etc., and other obstructions, are prevented from interfering with the air as it passes into the room; draughts are avoided, at least not so much felt as when the fresh air is admitted from below; and third, some maintain that this is the natural method, inasmuch as expired air from the lungs contains much carbonic acid gas; and as this is heavier than common air, it naturally descends to the floor or its neighbourhood, and is therefore most easily withdrawn by openings placed at or near it. There is much to be said in favour of the two first reasons, by reversing what at least is generally admitted to be the natural process of ventilation; but we do not

Fig. 36.



think much is to be advanced in favour of the third reason. No doubt, air expelled from the lungs does contain much carbonic acid gas; but the natural warmth of the body itself, as well as the heated condition of the interior of rooms generally, impart to the used air such a degree of temperature that its natural course in the great majority of cases is upwards. The upward course, moreover, is the easiest carried out in practice, there being greater structural and other difficulties in the way of withdrawing the used air from the bottom, and supplying fresh air at the ceiling of apartments. In Fig. 37, p. 119, we take an illustration from the *Civil Engineer and Architects' Journal*, showing the method of ventilating one of the schools in Paris upon this plan. "This building contains an elementary school *a a* for 400 children, and a drawing school *b* for 270 pupils. The ventilation is at the rate of 350 cubic feet per hour per person, and the warming is effected by two heating stoves *c c* with vertical tubes. The warmed air is supplied to each story by three vertical channels *d*, which discharge into a long wide passage *e* extending the whole length of the rooms, and into this passage external cold air can be admitted to regulate the temperature. The supply of air flows into the rooms horizontally near the ceilings, as shown by the arrows.

"The rooms of the drawing school *b* are open at night, and offer special difficulties in ventilation, from the large number of gas burners in use. The plan of abstracting the vitiated air close to the floor cannot be exclusively applied in this case, as it would cause the discomfort of pouring down air of 85° to 95° temperature upon the heads of the occupants. It is necessary, therefore, to allow the heated gases from the combustion of the lights to escape through the openings *f* in the ceiling, but at the same time fresh air is made to enter at the sides near the ceiling. In such cases, when the room has not attics above it through which the outlet openings in the ceilings can discharge, special flues are required to be made for this purpose, and these should be situated as far as possible from the points where the admission of fresh air takes place. By means of this plan of ventilation the temperature of the above rooms has been maintained until ten o'clock at night at 71°, at a height of five feet above the floor, and at an average of 75° near the ceiling; but before this plan was adopted these temperatures were 80° and 91° respectively.

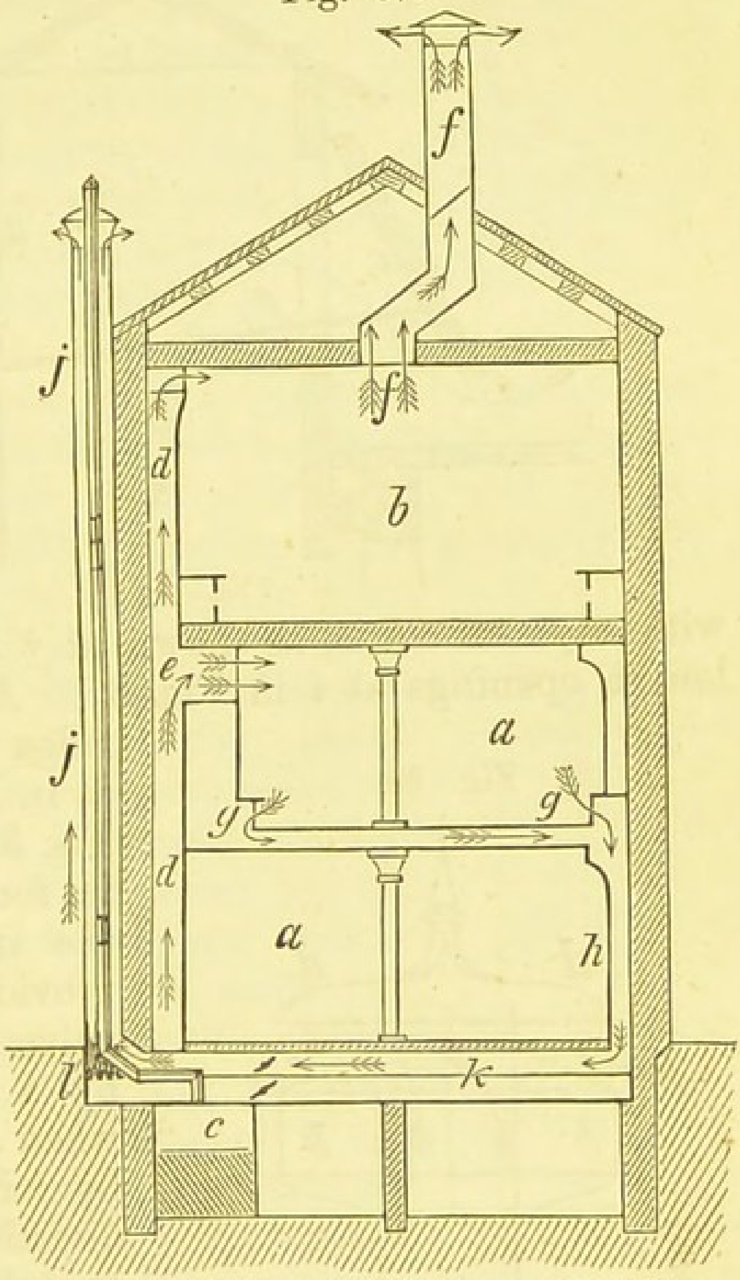
"The discharge openings should be made along both of the longer sides of the room, as shown at *g g* in Fig. 36, and should be as numerous as possible; and their total effective area should be such as to limit the velocity of the air passing through them to 2·3 feet per second. They communicate with descending passages *h*, converging below into a main discharge passage *k*, leading to the bottom of the discharging shaft *j*. The chimney pipes *i* from the hot-air stoves *c* are made to pass up this shaft for assisting the draught, but a small fire *l* at the bottom of the shaft is also requisite."

Where the velocity of the upward current in withdrawing flues or channels is too slow, a gas burner, or more than one, if necessary, may be applied at or near the opening into the room, so that it can be easily got at for the purposes of lighting and extinguishing. Or the burner may be placed at the foot of the discharging shaft. In most cases, however, where a chimney flue is in contact with or near the ventilating flue, the draught in the latter will generally be found sufficient in winter. In summer, extra means—as the gas jet, or the small furnace in the case of large flues, as named at the end of last paragraph—may be required to be adopted. On the advantages of the system of ventilating apartments by means of fire-places and chimneys, the following remarks by the distinguished authority, M. Morin, from whom we have already quoted, will be satisfactory to those who, like ourselves, believe that by them a power for ventilating rooms efficiently, and one easily and cheaply adopted, lies within the reach of all. "The suction," says M. Morin, "produced by simple fire places and chimneys, with sufficient area of opening for allowing the fresh air to replace the vitiated air, and without any mechanical apparatus, is consequently the most desirable means in the writer's opinion for effecting the ventilation of buildings, except in rare cases; and where special circumstances may necessitate the forcing in of fresh air by mechanical means, the action of a strong suction should also be added. This necessity never occurs in buildings where a continuous supply and removal of a nearly uniform quantity of air is required, but only when on the contrary this service has to be varied frequently between different portions of the same building, and when the quantities of air to be removed differ greatly from one day or from one hour to another,—as in the case of St George's Hall, Liverpool, where mechanical ventilation exclusively is adopted, and the quantity of air required varies in the extreme proportion of 1 to 50. In such cases it may become necessary, or at least useful, to employ mechanical apparatus in addition to the action of suction, in order to ensure a sufficient supply of fresh air."

The ventilation of staircases and water-closets should be carefully attended to. That of the latter will be noticed in a succeeding chapter on sewage and drainage. A few words will here find a fitting place on the ventilation of staircases. In what are called self-contained houses in Scotland, and in England, detached, the want of ventilation of the staircase, if not specially attended to, may not be so much felt where windows are provided, or where the rest of the house is well ventilated. In the majority of houses, staircases, with their landings, may be looked upon as mere apartments, lighted by windows in the ordinary manner, and which afford considerable facilities for admitting fresh, and allowing the withdrawal of foul air; but it is only in houses of considerable size, where the staircase—or the "well-hole," as the space is termed, in the interior of the houses which contains the stairs—is terminated at its upper part by a skylight. When so terminated, facilities are afforded for ventilating the staircase, which should be availed of. The skylight should be so designed, that it may terminate with a ventilating shaft, which may be made a highly ornamental feature of the general design. If the staircase could be lighted by a lamp, or "sunlight," which would be placed immediately below the opening of the shaft, the general effect would be very good, so far as the lighting up of the staircase from top to bottom would be concerned, while an immense advantage would be obtained in the increase of the velocity of the upward current of air by the heat produced by the lamp. The effect, however, of the glass in the skylight is to cool the air coming in contact with it, and thus reduce the force of the ventilation. To obviate this, the glass should be made double—that is, the skylight provided with two frames, both glazed, with a space between. This system of double glazed window is also excellent, where the temperature of a room—for example, that of an invalid—is desired to be kept as uniform as possible. Another, and not a small advantage in such a case, arising from the use of double windows in towns is, that the noise of street carriages, etc., is very much deadened.

The staircases in houses, arranged and constructed on the "flat system"—called, and with a force of truth not often recognised, "common staircases"—are very rarely, we may say never, provided with special ventilating appliances. True, they have all or nearly, windows. but those as a rule are never opened, if indeed they could be opened, so fastened down with dust of years are they; and even when opened, they—from their position—would not act efficiently as ventilators. Yet the necessity of carefully and efficiently ventilating these "common" staircases, is sufficiently obvious on consideration, decidedly so on personal inspection. In many cases the water-closets ventilate only into the staircase; and in addition, the air in the staircase is almost always infected by nuisances, too well and too familiarly known to dwellers in Scotch towns, where the flat system is adopted, to be here more particularly characterised. Where the staircases are terminated at their upper part by skylights, these skylights should be supplied with ventilating appliances; and if no skylights are in existence, ventilating shafts should be made to pass through the roof, communicating with the staircase in the ceiling, and admitting the free

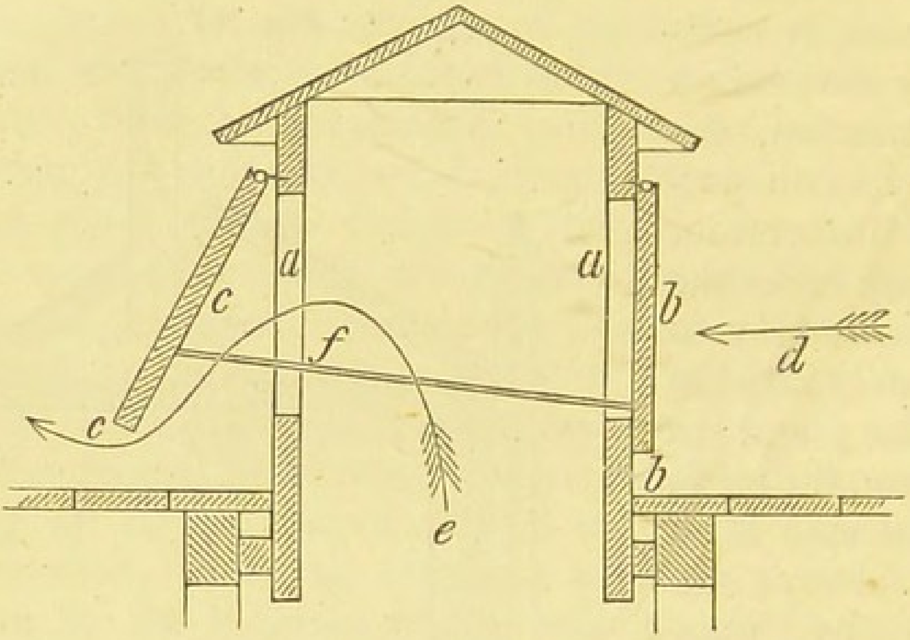
Fig. 37.



passage of the air through them to the external atmosphere.

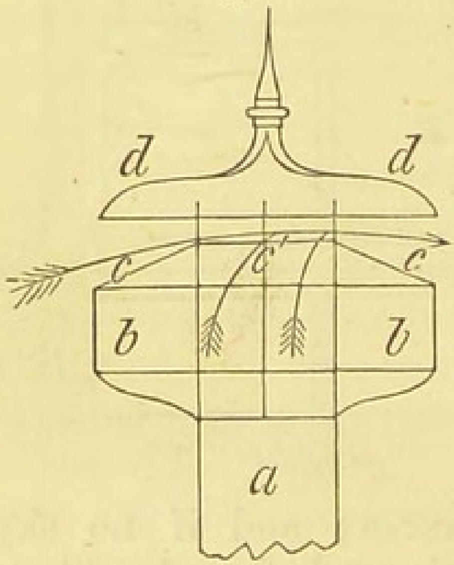
The tops of all discharging shafts should be provided

Fig. 38.



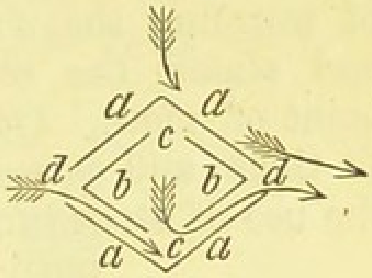
with caps or cowls, as shown at *f* in Fig. 37, or with louvre openings at *i* in Fig. 35. An excellent form of ridge ventilator for a roof, as in Fig. 35, is shown in Fig. 38. This being square in form, the openings in the sides, as *a a*, being provided with flaps or valves *b c*, so connected by a jointed rod *f*, that when one, as *a*, is closed by wind blowing in the direction of arrow *d*, the opposite flap or valve *c* is kept open, allowing the foul air to escape, as at arrow *e*. In Fig. 39, we illustrate the "Tredgold" cowl or cap, which has been extensively used—*a* is

Fig. 39.



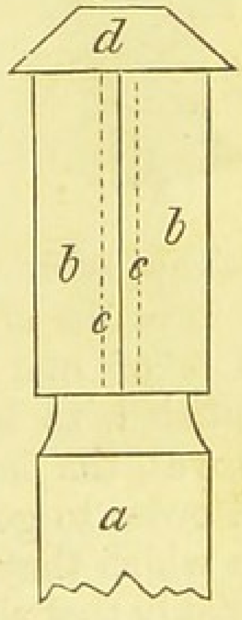
the termination of the ventilating shaft, which is finished with a circular metal part *b b*, extending outwards, as shown, to admit of the formation of an angular surface *c c;* the central part *c* is of course open, to allow of the upward passage of the air; winds blowing in the direction of arrow for example, in passing over the angular surface *c*, create a current upwards in the shaft *a*. The open part *c* is covered by a fixed cap *d d*, to prevent rain, etc., descending the shaft. In Fig. 40, we give plan,

Fig. 40.



and in Fig. 41, elevation, of "Kite's" angular-sided ventilating cap, which acts well in creating an upward current in the foul air shaft *a*, Fig. 41, with the aid of even moderately strong breezes. As shown in Fig. 41, the upper part of the shaft *a* is provided with metal shields *a a a a*, Fig. 40; *b b*, Fig. 41, the sides of which are set at an angle, as shown; these cover an internal part *b b*, the sides of which are also set at an angle, parallel to the sides of *a a a a*; from top to bottom of this part, rectangular slits *c c*, Fig. 40, *c c* Fig. 41, are made, to allow of the passage outwards of the foul air from the shaft *a*, Fig. 41; the ends of the shields *a a* are cut off, so as to allow of openings from top to bottom, as at *d d*, Fig. 40; the arrows show that the wind blowing from any

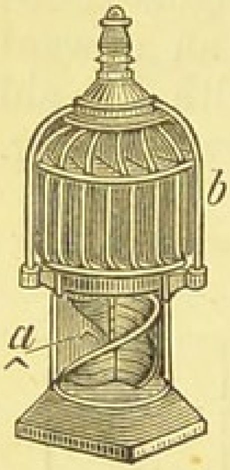
Fig. 41.



quarter meets with angular surfaces, and so meeting, tends to create an upward current in the shaft *a*, Fig. 40. Fig. 42, illustrates one of the Revolving Archimedian Screw Ventilators, patented by Mr J. Howarth of Farnworth, near Bolton, Manchester, which are also designed to create an upward current in the shaft. The screw *a* is made to revolve by the wind acting upon the vanes *b* of the upper part of the ventilator. These are now used in large numbers.

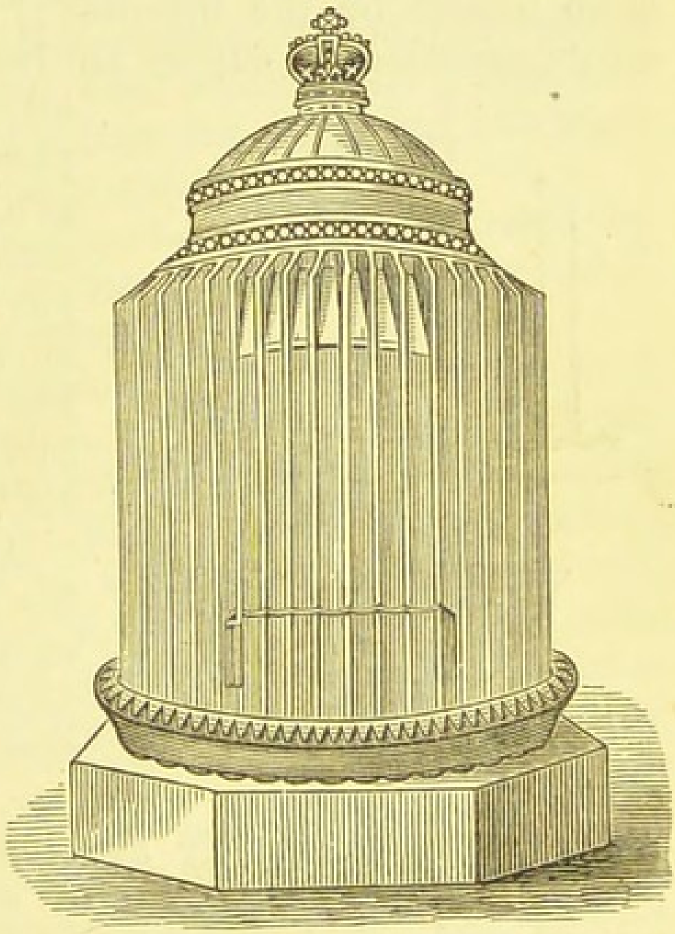
In a preceding paragraph, we referred to the method of warming the air of apartments by means of stoves, and stated the objection to their use in a sanitary point of view. Other objections obtain in this country to them, and possess such force that happily we think the use of stoves for warming rooms as a substitute for open fire-places will never become general amongst us. But they are nevertheless exceedingly useful in warming the air of apartments and buildings too large to be warmed by means of the ordinary fire-places, as also in warming the halls and lobbies of houses. The forms of stoves are so very numerous, and each inventor or maker claims for that which he places before the public such special and favourable features, that it is an exceedingly difficult thing to choose here one for description without incurring the charge of being invidious, or of favouritism. But as we have no interest in any one more than that of another, our mention of one or two will at least be considered fairly entitled to be free from such charges. In ordinary stoves, the heating surfaces are so ill-proportioned that in order to get up a good supply of warmth in the rooms in which they are placed, the fire has to be kept up so briskly that the metal is overheated, and all the unhealthy effects arising from this condition come into play. To obviate this, an exceedingly efficient yet simple method has been introduced of increasing the metallic and heating surfaces of the stove, so that a very small fire gives

Fig. 42.



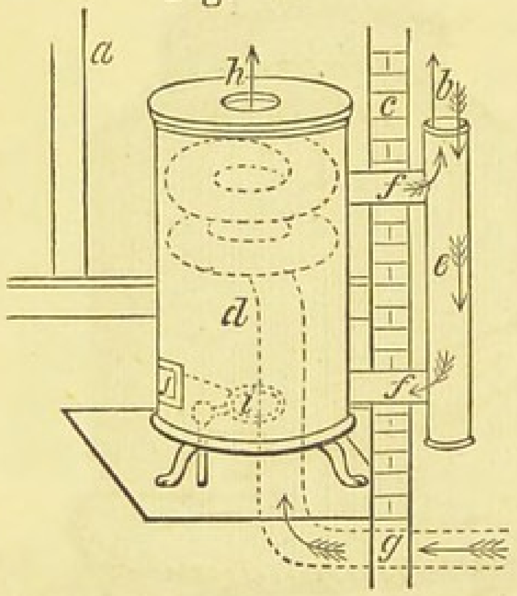
a large amount of warmth, and the overheating of the surface is prevented. This is done by merely adding projecting ribs to the exterior surface of the stove, or "gills," as they are termed, and which is illustrated in Fig. 43, which is the form of stove made by the London Warming and Ventilating Company (Limited), 23 Abingdon Street, Westminster, and which has been most extensively used.

Fig. 43.



Gas as a heating medium, when consumed in stoves more or less efficiently arranged, has been much advocated as good, cheap, and easily applied. As to its easy application there can be no doubt, hence for ventilating purposes we know of no method so likely to be generally adopted for raising the temperature of the air in ventilating shafts, when these form part of the construction of houses. As to its being cheap, experiments or trials have not been so extensively carried out, or if carried out, their results have not been so carefully noted, as to enable this point to be decided favourably. As to the goodness—that is in a healthy sense—of the system, much has yet to be done in the way of arranging and constructing stoves in which gas can be used so as to give a healthy warmth. The smell is almost always unpleasant, and it may be safely affirmed that this is indicative of the vitiation of the atmosphere. This difficulty has never yet been got over as a general rule, although the inventor of the apparatus, illustrated in Fig. 44, claims that by its use it has been so, and thoroughly, while at the same time he claims for it that it is "the only gas stove which retains the whole of the heat given off by the gas." In the illustration, *a*, the interior of the room; *b*, exterior of the building; *c*, wall; *d*, the calorigen (the stove is so named by the inventor;) *e*, a cylinder; *f*, pipes communicating to supply air for combustion, and carry off product; *g*, pipe for passage of cold air to calorigen; *h*, outlet for ditto after being made warm; *i*, gas burner; *j*, door. This apparatus is made by J. F. Farwig & Co., 36 Queen Street, Cheapside, London, E.C.

Fig. 44.



As regards the use of gas for heating large buildings, as schools or churches, the following notes of experience with it on the Continent, taken from *The Engineer*, will be useful here: "The method generally adopted, at Berlin, is that of placing a horizontal gas-pipe with three jets, within a stove made of sheet iron, and over the gas jets a piece of brass wirework, of which the openings are not more than $\frac{1}{25}$ of an inch in diameter. The cathedral of Berlin has a cubical contents of about 17,300 metres, and it is heated by means of eight of these stoves, each of which has 22 of these brass gratings, measuring $11\frac{1}{2}$ inches in length by $1\frac{1}{2}$ inch in width, making in all about half an inch square of grating for each cubic metre to be warmed.

The consumption of gas in raising the air within the edifice to the required temperature, an operation which takes three hours, is 83,400 litres, or 4·82 litres per cubic metre; to maintain the same heat afterwards requires only $\frac{7}{10}$ of a litre of gas per cubic metre.

"The parish church of Berlin, whose cubic contents is 13,800 metres, is heated by four stoves, each having fifteen brass gratings, each rather more than 12 in. long by 1½ in. wide, or little more than $\frac{1}{5}$ of an inch of grating per cubic metre to be warmed.

"The annual consumption of gas in the cathedral above mentioned is 2210 cubic metres, costing £20; this consumption is equal to 552 metres per stove, and 300 litres per $\frac{2}{5}$ of an inch square of grating.

"The consumption in Parisian churches warmed by gas is found to agree very closely with that of the cathedral of Berlin, but other cases give different results.

"The church of St Philippe at Berlin has a contents of 2780 metres, and is heated by two stoves 1m.40 high, 1m.10 long, and 65 centimetres in width, each having seven brass gratings 16 in. by 2 in., equal to $\frac{2}{5}$ of an inch square per cubic metre of the contents of the church. The annual consumption in this church is 1485 cubic metres, or at the rate of 410 litres of gas per cubic metre of contents. But this church is only warmed three times a week.

"The church of St Catherine at Hamburg is heated by eight gas stoves, each having 32 brass gratings 12 in. long by rather more than 1½ in. wide; the cubic contents of the edifice is 33,900 metres. The heating takes three hours and a-half, and consumes 220 metres of gas, costing about 27s. 6d., so that three litres of gas are required in this church per cubic metre of capacity; the temperature is kept up subsequently by the consumption of $\frac{3}{4}$ of a litre per cubic metre per hour.

"In the churches of St Mary and Nicholas in Berlin, and in Paris also, a kind of large rose burner has been substituted for the brass grating; these are known in France as mushroom burners (*champignons*). The result with these burners in the first of the above named churches is as follows :—The cubical contents of the building is 15,450 metres, and the consumption of gas in four hours is 150 cubic metres, costing about 35s., and as it is heated by ten stoves, each having three of these rose burners, the consumption per hour is 1½ cubic metres of gas per burner, and nearly 2½ metres for each metre of the contents of the church. In this case only we have the effect as shown by the thermometer, which is to raise the temperature of the church from one degree below zero to five degrees above, or from below thirty degrees to forty degrees Fahr."

It has been suggested by Mr Edwin Chadwick, C.B. —to whom sanitary science is very largely indebted— that an excellent, perhaps the best, method of warming buildings, in which considerable numbers of people are assembled, especially schools, is that which was adopted by the Romans in ancient, and the Chinese in modern times. In this the warmth is obtained by heating the floor surface by flues underneath, and of which Mr Chadwick gives the following brief account : "The Roman plans of floor-warming are displayed in the remains of villas found in the chief seats of their occupation in this country. Their hollow floors were mostly made by square slabs of stone, or of large tiles, supported by stone pillars a foot or eight inches high, or more, set upon a lower stone floor. The upper floors were covered with concrete, and often ornamented by tesseræ. Some of their hollow floors in this country were evidently warmed by coal, from the remains of coal soot ; in others they were warmed by wood. The fire-place for the coal-warmed flooring was mostly a small cylinder of red earthenware containing a mere handful of coal, through which the air was led by a down draught through the hollow of the floor—the draught being created by an upcast flue on the side of the chamber opposite to the fire-places, the tall chimney-flue acting as the longer leg of an inverted syphon. In some of the largest Roman constructions of this species, the heat appears to have been led underneath the long, distinct channels. But in some the warming was by the diffusion of heat through the floors amidst the uprights, which, I conceive, would be done by low heat led slowly, but long applied.

"I have been unable to get any detailed accounts of the Chinese methods of construction for the purpose, and I shall be much obliged to any one who will give me some. But the testimony is strong and decided, that the floor warming there is the most comfortable that has been experienced by Europeans. Marco Polo, the early traveller, notices it as extraordinary. The warming is effected with a comparatively inconsiderable amount of almost any sort of fuel."

There can be little doubt of this, that when the feet are warmed, the temperature of the body is maintained at a more comfortable point than when the upper parts of the body are warmed, and the feet are allowed to remain cold. Another advantage obtained by the warming of the floor surfaces of rooms, is that the system greatly aids the ventilation, especially as pointed out by Mr Chadwick: "As enabling a cold, and thence a more condensed air, a better quality of air to be breathed than any heat-expanded air. To those who have not had occasion to attend to the subject, it may be observed, if a given quantity of air, with a given quantity of oxygen, at a given temperature, be expanded in bulk by heat—say by a fourth—the inspiration of the lungs must be quickened in proportion, to obtain in the same time the same quantity of oxygen. In newly warming the Palais de Justice, at Paris, a warmed surface was placed for the feet of each judge. If the warmth were applied to the whole body, so as to raise it to the same temperature given by the foot warmer, the air breathed being more expanded would, I consider, be inferior in quality for the health.

"Before it became a practice to use foot warmers in railway carriages, the passengers were accustomed to close the windows as completely as they could. Since foot warmers have been introduced, windows are allowed to be more widely opened.

"The effect of foot warming, then, is to enable the body to sustain, with less discomfort, the import of cooler currents of air. Foot warming will, of itself, allow of doors and windows to be opened with less annoyance, and of itself will be conducive to freer ventilation. Indeed, Mr Blackburn's method of ventilating cattle-sheds by an open diaphragm along the roof would, in some instances, suffice. In many others I would propose, in addition to the warmed floor, the introduction of open fire-places, on Captain Galton's principle of warming with air pumped in, that is, fresh as well as warm, and the more active removal of vitiated air through the smoke chimney." This species of fire-place here named we have already described and illustrated in Figs. 31, 32, and 33.

This system of under surface heating now under consideration can, where the structural arrangements of the house are convenient, be easily carried out, and the maintenance is decidedly economical, as a very small amount of fuel will warm a large surface of floor. The heated air will also be more healthy than that obtained from the highly-heated surfaces of stoves, or hot-water pipes. No doubt, the position of some rooms will present greater difficulties than that of others, in the way of carrying out the system; obviously, for example, in the case of rooms in the upper floors of houses, as compared with rooms on the ground floor. But, even in the case of upper rooms in public buildings, the architect should have no great difficulty in designing the constructive details in such a way that the system of under surface heating may be easily carried out. With the wider spread adoption of fire-proof construction, as met with almost universally in certain districts of continental towns, greater facilities will be offered for the warming of buildings of all classes, by means of warm-air flues, as now suggested.

CHAPTER IV.

THE SMOKE NUISANCE IN TOWNS AND CITIES.

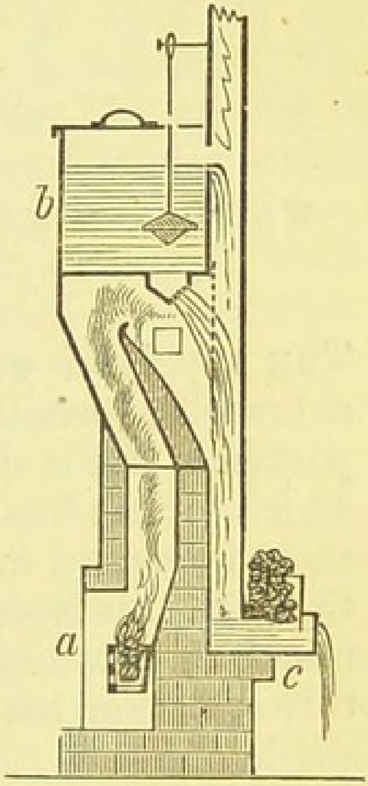
From what we have said in the opening remarks of last chapter, the reader will see the close connection which exists between the subject there discussed and that with which this chapter concerns itself. We have in these remarks pointed out, while showing the importance of ventilation in a sanitary point of view, that it is not alone sufficient that means be taken to supply air from the external atmosphere to the interior of our dwelling-places, but that it is necessary to see that the air so supplied be in itself pure. And we have also pointed out the many sources from which atmospheric contamination is derived; so numerous indeed, and so potent, that to get pure air to supply our houses with, is in some districts by no means an easy matter. Chief amongst the sources of atmospheric contamination is the smoke arising from the countless chimneys of private dwelling-houses and public buildings of our towns and cities, and the mephitic vapours arising from the various industrial operations carried on in many of our manufacturing districts. And although these latter and most dangerous vapours are not so plentiful in ordinary—*i.e.*, non-manufacturing towns, or may not in some districts be met with at all—still the smoke, even in its most innocent form, as passing from the chimneys of private dwelling-houses, when intensified by the number of chimneys—which form not the most inviting architectural feature of our populous towns—is, if not dangerous to health, as positively and appreciably contaminating the atmosphere, nevertheless a nuisance, and one which is greatly and justly complained of. But like nearly all other nuisances affecting the sanitary condition of our towns, it involves a waste, and a large waste. From the imperfect combustion to which our coal is subjected, both in ordinary fire-places and factory chimneys, a very large percentage is sent into the air in an unconsumed state in the form of clouds more or less appreciable to sight—from the dense black of those passing from the factory, to the lighter ones which issue from our private-house chimneys. This smoke—so patent to our sight—is in fact made up of particles of unconsumed coal, which we call soot. And this soot descending in never-ceasing showers on the places below, involves another source of waste, in the injury it does to houses, furniture, goods in shops and warehouses, and to linen worn on the person. No doubt this last source of waste will to some seem too trifling to be here named along with other sources of waste of greater—at least apparently greater—moment. But it is not a trifling source of waste. Space does not here permit us to give the calculations which have been made of the money lost in one of our large manufacturing towns, not only from the extra sums spent in extra washing of linen, arising from the foul condition of the atmosphere, but from the deterioration and rapid wearing out of the linen itself, arising from its being so frequently washed. Viewing, however, the whole of the sources of waste, and also the discomfort of the presence of soot in the atmosphere, arising from what is called the "smoke nuisance," it is not to be wondered at that attempts have been made to lessen it during the last few years, by rendering the production of smoke in public works an offence punishable by fine—attempts, however, which have not been so successful as the framer of the Acts—under the operation of which these fines are exacted—seem to have anticipated, when they were drawn up and passed. Smoke consumption, so far as the public works are concerned—for it will be long before private houses can be brought under the operation of any Act—is an improvement yet to be carried out extensively and efficiently, notwithstanding the host of patent appliances which have been brought out, by the use of any one of which it is stated it can be effected. The practical position of the question, however, is, that the Acts are much more frequently broken through and evaded than followed.

But it is indicative of the difficulties which surround nearly all sanitary questions, that, in connection with this, the doing away with the black smoke nuisance, which is generally looked upon as an improvement in city life greatly to be desired, is by some looked upon as no improvement at all; rather indeed a new source of danger to public health. In other words, it is maintained by some, that the black smoke arising from the imperfect combustion to which coal is subjected in all domestic and nearly in all industrial fire-places and furnaces, is comparatively innocent; that the more perfect the combustion is, the more deadly are the gases resulting from it; and that while the comparatively innocent gases in black smoke are carried away from the lower zone of the atmosphere, the deadlier ones, the products of more perfect combustion, have a tendency to descend towards it. However much opposed this opinion may be to the one which is popularly, and we may say almost universally, held on the smoke question, the points involved possess so much interest in relation to the public health, that we deem it right to glance at them, in order to draw attention to a view of the subject which has been singularly overlooked, and which further investigation may yet prove to be correct. The point is indeed of so much importance that it should be fully investigated, for it is just one of the possibilities connected with the subject, that we may be legislating altogether in the wrong direction, looking for improvement where improvement is not possible. It is right to state that the view here referred to, namely, that black smoke—nuisance though in some respects it is freely admitted to be—is safer in regard to the public health, than would be the products of a perfect combustion of fuel; in other words, "non-consumption" is safer than "consumption" of smoke. This theory was first promulgated in a paper read by Mr Spence of Manchester, before the Literary and Philosophical Society of that town. Let us, in the brief remarks which we have to offer upon the subject, first glance at the process of the combustion in ordinary fire-places and furnaces of coal, which is composed of sulphur, carbon, oxygen, nitrogen, hydrogen, and ash—this last made up of silica, aluminum, oxide of iron, etc. This process is of a twofold character—distillatory and combustive—the first being that which at first takes place in burning coal; the second or combustive process comes into play only at the later stages of the operation. When fresh coal is put upon an open fire-place, already containing fuel, partly consumed, the whitish cloud, which is first seen to arise from the coals, is simply the evaporation of the moisture present in them. The pieces of coal next disintegrate or begin to crumble in pieces, and the vapour changes from a whitish to a yellowish colour. The products of this give rise to flame, which spreads over the surface of the coals. At this stage much of the carbon is given off, some of this in the form of carbonic oxide or acid, but the major portion in the form of soot. As the temperature increases, and air is largely admitted, the mass becomes red, on the surface of which a blue flame plays, this resulting from the combustion of the carbonic oxide, or its conversion into carbonic acid gas. This stage marks that of true combustion, the products of which are sulphurous acid, arising from the combustion of the sulphur, and carbonic acid gas, arising from the combustion of the carbon. The process is illustrated in the furnaces used in industrial operations, although, from their special construction, and the tall chimneys with which they are connected, it is much more rapid than in the open fire-place. The products, then, of the consumption of coal in fire-places and furnaces under ordinary circumstances, which form the black smoke so greatly complained of—and which may be called the distillatory process—are nitrogen, water, carbonic oxide gas, carbon, as soot, sulphur, and carbonate of ammonia. "Of these constituents of the smoke, only one is of a character positively deleterious to health; nitrogen gas is purely negative, and is not altered by passing through the fire. The water needs no defence. The solid carbon, against which all the cry is raised, is guiltless of all deleterious effect on human health; is one of the most anti-putrescent bodies; and while floating in the atmosphere, does all that it can to arrest and destroy noxious and miasmatic vapours. Sulphur, again, in its solid form, is perfectly innocuous. The only objectionable body is the carbonic oxide gas. This is certainly poisonous, being equal in that respect at least to carbonic acid gas. It has, however, this advantage, that, while carbonic acid gas has a specific gravity of 1·52, air being 1·0, the specific gravity of carbonic oxide is only ·96. It is thus not only aided in its escape by the law of diffusion, but its lightness always prevents it from any tendency to descend to the human dwellings around." Let us now glance at the results of the process of perfect combustion, which creates no black smoke clouds, and is the state of matters so much wished for by the advocates of smoke consumption. We have already named carbon as one of the elements of coal, which is its largest constituents, there being 28 per cent. of volatile, and 58 of fixed carbon. When the coal is thoroughly consumed, the products are water, carbonic acid, and sulphurous acid, which are carried up the chimney, and ashes, which remain behind. Of these products, water is harmless, but the other gaseous bodies are highly deleterious to health. Carbonic acid gas being heavier than air, may be poured from one vessel to another; and it lies insidiously at the bottom of wells, pits, vats, etc.; and causes asphyxia in animals which enter into any place containing it. Hence, when it issues from a chimney, it tends to sink, from its greater weight than atmospheric air—in fact, to the strata of the atmosphere in which the inhabitants live. No doubt, the principle of diffusion of gases may prevent its producing those fatal consequences which it does when in a pure state; but were thorough combustion completely carried out, as the smoke consumers desire, in large manufacturing towns, this gas might be found mingled with the air the inhabitants breathe, in larger quantity than would be safe for their health.

Sulphurous acid, the other gaseous product of the thorough combustion of coal, is also heavier than air, and even than carbonic acid gas; and, although comparatively—some say positively—harmless to animal, it is certainly destructive to vegetable life. These, then, are the noxious gases which would be produced from the perfect combustion of coal, and from the consumption of smoke. It therefore seems a fair subject of inquiry, whether the dense volumes of smoke, which are vomited forth by our thousands of chimneys are, or are not, prejudicial to health; and, if prejudicial, if they are, as some maintain, more so than the almost invisible gases which issue forth from them, when the combustion is more complete. So far as the two positions are concerned, and which we have already explained, without offering any opinion of our own on the point, it would appear that the products of imperfect combustion are not so dangerous as those of perfect combustion. In the one case, by the consumption of one hundred pounds of coal we obtain twenty-nine pounds of carbonic oxide gas, which rises and mixes with the air in its higher regions, and a large proportion of unconsumed carbon or smoke, which is only injurious in a limited sense; while, in the other, if we avoid the creation of soot, by carrying out perfect combustion, we increase the production of carbonic acid gas—a gas so deleterious to health that 7 per cent. of it diffused in the atmosphere is fatal to life, and which is so heavy that it has a great tendency to descend to, and mix with, the zone of air in which we live.

We have said that it will be long before attempts will be made to render it compulsory on the inhabitants of dwelling-houses, to abate the smoke nuisance by contrivances adapted to ordinary fire-places. A great deal, however, can be done in the way of preventing the formation of much soot, by managing the burning of fuel in the grate, as well as by adopting one of the many new forms of grates in which the fuel is consumed, more in accordance with true principles than in those generally in use. But it is worth noting that special contrivances have been lately introduced, by which it is proposed not to prevent the formation of soot, but to withdraw the solid particles from the ascending vapour from chimneys, before it escapes at the top. We figure the arrangement introduced by Mr Richardson, and fully explained, with other cognate subjects, in his work, "The Smoke Nuisance, and its Remedy by Means of Water, with Remarks on Liquid Fuel:" Fig. 45 "represents a section of a small stove, with its flue experimented upon by the writer to ascertain the worth of the water-spray process. The lower part of the stove is of brick; the upper part, with the cistern, is of zinc; *a* is the fire-place, *b* the cistern of water, and *c* the soot receptacle. The coal fire was lighted, and as soon as dark smoke appeared at the chimney-top, the water-valve was lifted, and about sixteen fine jets of water were sprayed against a piece of loose perforated zinc, suspended in the flue, as shown in the figure; the smoke had to turn towards the water, and to pass through it to get to the flue above. On the instant the water was applied, the smoke appeared at the chimney-top of a light colour, and it came out at the soot receptacle nearly as much as it did at the top, and of a similar light vapourish character—a sure sign that it was drawn down by the current of water. Soot in a large quantity was soon seen in the receptacle; two small pieces of glass were placed in the flue, that the operation of the water might be observed."

Fig. 45.



CHAPTER V.

WATER, AND WATER SUPPLY TO HOUSES IN TOWN AND COUNTRY DISTRICTS.

THE supply of water of good quality to our houses, is a branch of sanitary science of the utmost possible importance, and is therefore worthy of the earnest attention which of late has been given to its details on the part of those interested in maintaining the health of our population. Still it is suggestive of our national indifference to nearly all questions relating to public health, to note, that this attention has only of late years been given to the whole question. It is not long since, that in many districts in our large towns, water, if not dearer in a money point of view, was more difficult to be obtained by the poor than beer. Nothing, indeed, could be more melancholy than the condition of such districts, in respect of water supply, as described in the reports published some twenty years ago. And, although matters since then are much improved, still it is evident, from what is still stated to be the condition of our large towns as regards their water supply, that very much has yet to be done before they can be said to have that supply—*first*, regular; *second*, abundant; and *third*, of good quality.

In offering the brief remarks on the subject which our space will admit of, we shall consider them under the three heads here named, taking them in the inverse order. And *first*, then as to the good quality of water:

Considering the many-sided aspects which all the branches of sanitary science present, it is perhaps not to be wondered at, that all have given rise to keen discussions amongst scientific men, and the result is such a diversity of opinion, that it is sometimes exceedingly difficult to arrive at a conclusion as to which of the many views held by various parties is correct. The point now under consideration, namely, the quality of water, is no exception to the rule, as rule it may almost safely be called. What constitutes a pure water? and what influences are those which contaminate a water otherwise pure, or supposed to be pure? are questions which, to judge from the discussions amongst our scientific men, are not yet decided. Two samples of water may be taken, and if their good quality was to be judged by the eye alone, one would be pronounced pure, the other impure; and yet the one which pleased the eye less, as being less limpid and clear, might be the purest in the sense of being the most healthy; while the clearest water might, if partaken of regularly, be very prejudicial to health. The clear water may contain saline substances prejudicial to health, it may be contaminated by the action of lead, it may have absorbed gaseous impurities, or may have been rendered impure by putrescent organic substances, derived say from sewage water, or from passing through soil impregnated with decaying organic matter. Hence the necessity to ascertain, as far as can be ascertained, by careful chemical analysis and physiological experiments, whether the water proposed to be supplied to houses is likely to be prejudicial to health, or otherwise. We here, however, would point out the necessity of looking for aid, in this useful direction, to a quarter other than that of mere chemical investigation, namely, as suggested above, by carefully conducted physiological experiments. For, while chemical analyses may show that a water contains certain constituents, it is not a truly scientific mode of treating the subject, to assume that these will exercise a prejudicial influence upon the health of those who take them. It is just possible that a properly conducted series of trials might show that the waters thus condemned were healthy in their action. A very wide and carefully conducted range of experiments has yet to be made in the double direction of physiological, as well as chemical inquiry, before the question as to what constitutes a really pure and good water can be decided.

The most popular and the most easily recognised standard by which to judge of the quality of water useful for domestic purposes, is that of its "hardness." Water derives its hardness from certain saline substances contained in it, of which the principal one met with is chalk (carbonate of lime), stucco or gypsum (sulphate of lime), and common salt (chloride of sodium). These are met with in nearly all waters, and do not of necessity render them impure, in the sense of being unhealthy, but when in excess they render the water very hard.

"The most important portion of the earthy salts," says Dr Clarke, a great authority on the water question, "may be reckoned the bi-carbonate of lime. The whole salts present, whether earthy or not, may be distinguished into two parts, according as they are neutral to test paper, or alkaline to test paper—the neutral portion, and the unneutralised portion. The unneutralised portion consists entirely of bi-carbonates, those of lime and magnesia, which are the earthy bi-carbonates, and in some waters, those of potash and soda, which are the alkaline bi-carbonates. The neutral portion consists of the neutral salts of earth and alkalines, such as gypsum and common salt. Salts of iron occur also occasionally in waters that are in use. Such salts impart an inky taste to the water, and they give a yellowish tint to lime that is washed by the water containing them. They, too, produce hardness. Waters known as chalky are those having for their principal ingredient of impurity the bi-carbonate of lime. This is derived from chalk or limestone, the salt being changed from an insoluble to a soluble one by a double amount or dose of carbonic acid. The earthy salts of magnesia, above noted as belonging to the most material of the earthy salts, are frequently present in minute quantities, with the bi-carbonate of lime. In some instances . . . the salts of magnesia are in so great proportion that a distinct and peculiar species of water is obtained. The neutral salts of lime, known as gypsum or sulphate of lime, act on water somewhat in the same way as the bi-carbonate of lime, that is, render the water hard."

The hardness of water is popularly recognised by the difficulty there is in making a soap lather with it, the salts in the water decomposing the soap and curdling it. With soft water—that is, water in which no salts of lime are present, or, if present, only in minute proportions—the soap is not decomposed, and no curdling is produced. When soap, therefore, is curdled, it is for detergent purposes, whether of clothing or of person, just so much wasted. Hence the superior economy of soft water for washing purposes, of which more presently. It would be easy here to give ample details showing the enormous outlay of soap in washing of clothes which the use of hard water entails, and its wasteful effects also in cooking. This popular method of testing the hardness of water has been taken advantage of by Dr Clarke of Aberdeen, a gentleman whose researches as to the impurities and qualities of water are well known, and the result has been an extremely delicate test, which may be used where it is desirous to know the exact rate of hardness of a certain quantity of water. This test consists in the use of a solution of soap, the strength of which is accurately ascertained. In proportion to the quality of this solution required to form a lather with any quality of water, so is its degree of hardness. In the great majority of cases, the hardness of water is caused by the presence of chalk (carbonate of lime) in solution. Dr Clark of Aberdeen patented, some years ago, a method of freeing water from this impurity by a method as simple as it is efficacious. The fact that chalk is the principal ingredient in hard water has, therefore, given rise to a method of estimating the different degrees of hardness in different qualities of water, also introduced by Dr Clark. Thus, where one grain of chalk is found dissolved in a gallon of water, the hardness is said to be of one degree; where two grains are dissolved in a gallon, two degrees; and so on.

This standard has been widely, if not universally, adopted in instituting comparisons between one quality of water and another, although it possesses certain defects which have led another standard to be adopted by the Registrar General in drawing up these reports on public health with which we are all more or less familiar. This standard is based upon the number of grains (degrees) of carbonate of lime or chalk found in 100,000 grains of water. As this amount very nearly represents the number of grains in a gallon, 70,000, the new standard is easily reduced to the old, or Dr Clark's, by simply multiplying the degrees indicated by the new standard (the Registrar General's) by ten, and dividing the quotient by seven, the result being the number of degrees according to the old standard, or that of Dr Clark. In following up, therefore, any investigation into the quality of water, so far as its degrees of hardness are concerned, it will be necessary distinctly to understand by which of the standards the degrees of hardness are ascertained, the difference between them amounting to nearly one-third.

It is very difficult to decide the point at which a water may be said to become hard. Much depends upon the purpose for which the water is to be used. If for drinking, a very hard water may be employed, and yet be considered soft; while, if used for washing purposes, it will in reality be very hard. If the water is to be used for washing purposes, or for certain manufacturing processes, for which soft water is best, inasmuch as the degree in which the water tends to curdle soap is the real measure of its value for these purposes, the best test by which to ascertain its value is unquestionably the soap test above described. When the water is to be employed, as in the case of supplies to towns, for all purposes alike, whether for cleaning houses, washing, cooking, or drinking; and seeing that the proportion of water used for drinking is very small as compared with the proportion used for the other purposes above named, water with the least degree of hardness should be taken, if choice is given, which, however, is by no means always the case. An able authority on the subject states that, for general town purposes, a first-class water should not exceed five degrees of hardness, a "second-class water" from five to ten, and a "third-class water" ten to twenty degrees.

But, in considering the hardness of water, a distinction should be noted, and this is, that a water may be hard from the presence of salts, which cannot be removed from it, which we would thus call a permanently or fixed hard water; while it may be hard from the presence of salts, which can be removed, and which is therefore a water hard only under these circumstances, so that the hardness may, by certain processes, be removed. Where the hardness of water arises from the presence of sulphate of lime, it cannot thus be made soft; but if by the presence of carbonate of lime or chalk, it may be made soft, either by boiling, or by the process of Dr Clarke, presently to be described. Boiling softens water to a considerable extent, but neither so quickly and so thoroughly as Dr Clarke's process.

Soft water is, however, not only valuable as being the best for washing, but as being also the best for cooking purposes. There can be no doubt of the fact—for it is one based both upon practice and theory—that soft water certainly extracts much more quickly, and apparently more efficiently, than hard, the nutritive portions of meat, in which boiling is useful, and in extracting the full "natural value in infusions," such as tea and coffee.

Nor should the prejudicial influence of hard water, as stated by the great majority of medical men, upon the health of the individuals regularly partaking of it, be overlooked. From the very earliest periods in the history of medical science, authorities have noticed the deleterious influence upon the system induced by a continuous use of hard water. From the sick room, an eminent modern authority states that it should be rigidly excluded. Even with persons in good health, the use of it is said to be almost immediately marked, if they have been previously in the habit of using soft. For the purposes of personal cleanliness, we have stated that soft water is superior to hard. Few accustomed to use soft water will return to the use of hard, if they can at all do otherwise. "The extension of the practice of bathing depends upon its agreeableness, and its agreeableness on the softness and the clearness of the water used for baths. Hardness in water not only lessens the pleasantness of washing, but hardens and roughens the skin. It has been remarked, both in England and America, that in such districts as have a natural supply of soft water, there is exhibited in the inhabitants a freshness of complexion not to be found in any hard-water district."

In all cases, therefore, where opportunity is afforded—and this obviously will be more frequently had in rural and suburban, than in town districts—provision should be made to store up rain water. In the lowest homes, means should be adopted for receiving and storing it up. Gallons upon gallons of valuable soft water, in some towns, are allowed to go to waste without a single effort to retain a drop, while the inhabitants of other towns use all means to save it.

As we have already named, Dr Clarke has introduced a method of softening water rendered very hard by the presence of carbonate of lime or chalk, which has been very successful:

"To understand the nature of the process, it will be necessary to advert, in a general way, to a few long known chemical properties of the familiar substance, chalk; for chalk at once forms the bulk of the chemical impurity, that the process will separate from water, and is the material whence the ingredient for effecting the separation will be obtained. In water, chalk is almost or altogether insoluble, but it may be rendered soluble by either of two processes of an opposite kind. When burned, as in a kiln, chalk loses weight; and, if dry and pure, only nine ounces will remain out of a pound of sixteen ounces. These nine ounces will be soluble in water, but they will require not less than forty gallons of water for entire solution. Burnt chalk is called quick lime, and water holding quick lime in solution is lime water. The solution thus named is perfectly clear and colourless. The seven ounces lost by a pound of chalk on being burned, consist of carbonic acid gas—that gas which, being dissolved under compression by water, forms what is called soda water. The other mode of rendering chalk soluble in water is nearly the reverse. In the former mode, a pound of chalk becomes dissolved in water, in consequence of losing seven ounces of carbonic acid. To dissolve in the second mode, not only must the pound of chalk not lose the seven ounces of carbonic acid that it contains, but it must combine with seven additional ounces of that acid. In such a state of combination chalk exists in the waters of London—dissolved, invisible, colourless, like salt in water. A pound of chalk dissolved in 500 gallons of water, by seven ounces of carbonic acid, would form a solution not sensibly different, in ordinary use, from the filtered water of the Thames in the average state of that water. Chalk, which chemists call carbonate of lime, becomes what they call bi-carbonate of lime when it is dissolved in water by carbonic acid. Any lime water may be mixed with another, and any solution of bi-carbonate of lime, without any change being produced. The clearness of the mixed solutions would be undisturbed. Not so, however, if lime water be mixed with a solution of bi-carbonate of lime. Very soon a haziness appears; this deepens into a whiteness, and the mixture soon acquires the appearance of a well mixed whitewash. When the white matter ceases to be produced it subsides, and in process of time leaves the water above perfectly clear. The subsided matter is nothing but chalk."

Such is the basis of the process. Hard water contains chalk, in the form of a bi-carbonate of lime. By the addition of lime water, the chalk is precipitated, and the water left above is clear, colourless, and soft, not holding, in any sensible degree, either a solution of quick lime or bi-carbonate of lime. The process, in domestic arrangements, is easily carried out, by having a quantity of ordinary lime water in a well-stoppered bottle, using it to soften the water as required. Wherever the plan has been adopted, it has been successful.

Mr Holland, who softened the water supplied to his house, has stated that it paid for the expense of softening over and over again, in the mere item of saving in tea. The proportion of lime to the water is one to thirteen. Two jugs may be used, one holding thirteen times as much as the other. For each jugful (of the largest kind) of hard water used, one of the small jugs of lime water is to be used. The chalk should be allowed to deposit itself at the bottom, and the supernatant liquor decanted off.

The following is Mr Holland's method of mixing the lime water with the water to be softened—the lime only having to be supplied once or twice a month: "A jar is placed in the cistern, so that the top shall be on a level with the water line; into this jar the quick lime is put. A zinc dish is placed on the top of the jar; the water supplied to the cistern is delivered to this; a pipe in the centre of the dish conveys the water to the interior of the jar; in this pipe a notch is cut. The size of the notch of the pipe should be so arranged, that of the water entering the zinc dish, only one-thirteenth part enters the jar through the notch and pipe; the remaining twelve parts enter the cistern through an aperture in the side of the zinc dish. The thirteenth part, passing down the notch in the pipe, mixes with the lime in the interior of the jar. A pipe is carried to within a short distance of the bottom of the jar, and communicates with the cistern at the level of the top. By this arrangement, while twelve parts of the water pass into the cistern, one part passes down to the jar, and is again delivered to the cistern, mixing with the hard water in the required proportion, and softening it. In cisterns where this plan is adopted, the water should be withdrawn by a tap placed at some distance above the bottom; this will prevent the deposited chalk from being disturbed, while the water is being withdrawn."

For drinking, hard waters are more agreeable to the palate than soft water, but this does not arise, as is generally supposed, altogether from the saline particles which give hardness to it, but chiefly from the gases which it contains. Some waters, notoriously polluted with sewage and organic matter, are found to be the most agreeable possible to the palate, but this, from the fact that they contain a large per-centage of fixed gas. Water well "aerated" is always agreeable to the palate, being known as "sharp;" but this quality may be found in perfectly soft water, as well as in hard. Water not well "aerated" is not pleasant to drink; as, for example, water which has been boiled. This "aeration" of water is an important point, and one which has not been sufficiently attended to in the discussion of the water question. While the presence of pure air, or "good aeration," tends to make the water not only pleasant to the taste, but healthful to the body; on the other hand, water subjected to an impure atmosphere, and thus being in a condition of "bad aeration," exercises a bad influence on the health of those partaking of it. Water possesses a remarkable power of absorbing and condensing many of the gases placed near or in contact with it. This power of absorption is such, that it takes up many times its own volume. A very simple, yet conclusive, experiment as to this power may be made, by allowing a glassful of distilled water (free from all gas) to remain exposed to the air. If tested a few day's afterwards, it will be found to have taken up an appreciable quantity of carbonic acid gas and oxygen. If placed under a glass jar, with sulphuretted hydrogen, the water will be found to have absorbed it. The carbonic acid in respired breath will be taken up by water, if passed through it by means of a tube. Dr Lyon Playfair gives a remarkable exemplification of the absorbing power of water. "One of my assistants," he says, "was making experiments with an oil which had the smell of the concentrated urine of a male cat. The smell was insufferably offensive, and was so readily absorbed, that it was impossible to drink the water placed in the room. . . . . Every vessel containing liquid in the room soon became contaminated with this horrible smell." The same authority states that he has not the least doubt, that water exposed to an impure and noxious atmosphere, is capable of absorbing noxious and impure matters, and in this way proving injurious to health. Dr Hassell has detected sulphuretted hydrogen in the water in cisterns placed above water-closets and privies. Rain water in the neighbourhood of large towns takes up the gases floating in the atmosphere. Thus Dr Angus Smith detected traces of ammonia in the rain water falling in the neighbourhood of Manchester. According to Professor Hoffman, 1000 gallons of water dissolve, at the common temperature, 46 gallons of oxygen, 25 gallons of nitrogen, 2500 gallons of sulphuretted hydrogen, 1000 gallons of carbonic acid, 500,000 gallons of ammonia. This latter gas is that which escapes from the decaying matters and refuse filth retained in the close courts and in the ill-cleansed districts of towns ; the gas, under these circumstances, always carrying with it vegetable or animal matter in a high state of putrescency. Dr A. Smith has gone very fully into the question of the aeration of water. The result of his investigations proves, as we have already explained in the opening paragraphs of Chapter III. on Ventilation, that the impurity of water in crowded rooms, is not owing solely to the presence of carbonic acid, but really to the presence of organic matter in the air. Hence, another reason why water becomes so rapidly impure, if placed in close and crowded apartments. On this point we may sum up our remarks, by the following apposite matter from the report of the General Board of Health : "It stands, then, upon the evidence of common observation, and upon the testimony of the senses of taste and smell, that waters of the same source, and composed of the same chemical constituents, may be largely varied in quality, by exposure to different atmospheres ; and it rests upon the evidence of medical observation, that impure water taken into the stomach, occasionally produces more sudden and violent effects, than impure air introduced into the system by the respiratory apparatus. This may depend, in part, on the physiological fact that water taken into the stomach passes directly into the blood by venous absorption; that it makes no selection, but admits at once whatever is presented to the imbibing veins; and in part also on the fact, that water being capable of holding in solution a greater amount of foreign matter than air, noxious matter may accumulate in water to a greater extent than in air. It may, indeed, be held as true, that they who drink water that has stood for a time, or been exposed in a town, drink town air, whilst they who drink water, brought direct from an elevated rural district, without exposure, are drinking country air. There can be no doubt that certain gases deteriorate the quality of water—such as sulphuretted, carbonetted, and phosphoretted hydrogen. These are generally derived from decomposing substances, contained in the water. Sulphuretted hydrogen gas is generally in these cases produced by the decomposing organic matter reacting on the sulphate of lime, or any other sulphate, which the water may contain, thereby engendering the sulphuretted hydrogen. This gas, in its concentrated form, is highly prejudicial to life, and if introduced into the stomach, by the medium of water, acts injuriously on the health. A simple method of testing the water, in order to discover the presence of this gas, is to add a few grains of the acetate of lead (sugar of lead) to a wine glassful of the water. If a precipitate of a brownish colour is produced, it is a proof that sulphuretted hydrogen exists. The smell proceeding from bad water is produced by the evolution of this gas and the phosphuretted hydrogen."

From what we have now stated as to the aeration of water, and the readiness with which it takes up or absorbs deleterious gases, the importance will be seen of so placing cisterns for the storing up of water for domestic purposes—especially for cooking and drinking—that they will not be near the sources of such gases. This at once condemns the practice too widely—we might almost say universally—adopted of having the cistern near to the water-closet, or connected with the drains in such a way that the foul air from them can ascend to, and come in contact with, the water contained in them. No overflow pipe should be connected with the drains, if it can be at all avoided. The better way is to pass the waste water to the street gutter, where it will do good rather than harm in cleaning it. Should the time ever come when we have rainfall sewers as well as those for household sewage, the proper outlet for overflow of cisterns will be to these. The cistern, then, instead of being placed in a close, dark, and confined situation as it generally is, should be in a part of the house well lighted and ventilated, so as to be of easy access at all times, and as far as possible from the water closet. In another part of this chapter we shall describe the system of water supply which proposes to dispense with the necessity of having cisterns at all.

But a water may appear pure to the eye, and be found agreeable to the taste, and yet be an eminently unhealthy water to be regularly partaken of. This may arise from its coming in contact with substances between which an action sets in, resulting in the formation of an unhealthy constituent, as in the case of the action of water upon lead—a material almost universally used to line cisterns with, and for service pipes—or impurities may be derived from organic substances, such as sewage matter allowed to pass into the water.

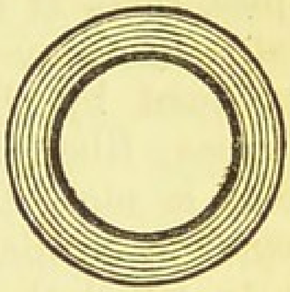
With regard to the action of lead upon water, much has been written and said, and not always with the precision with which scientific questions should be discussed. Viewing indeed the various opinions held upon the subject, and held moreover by men all of them entitled, from their position in the scientific world, to give an opinion, it is rather difficult to say whether lead, when present in water, acts so prejudicially upon its quality as has been stated. Possibly all that can be said is, that the balance of evidence is more in favour of the opinion that water acted upon by lead does prejudicially influence its quality rather than that it does not. It will, therefore, be right here briefly to examine the points connected with the question. Air and moisture coming in contact with lead oxidises it more or less rapidly, and produces what is called a hydrated oxide, when the lead has been in contact with pure water. Alternate dryness and wetness of the surface of the lead excites the oxidising influence to greater activity than when the lead is constantly covered with the water. The lead at the line of evaporation, or level of the water, is acted upon much more quickly than at any other part, hence if the level is pretty constantly maintained at the same point, the lead is rapidly eaten through or corroded at this line. The kind of lead also, or rather the uniform quality of it, seems to exercise an influence upon the rapidity with which it is oxidised by air and moisture. It would appear from recent investigations that the more homogenous the texture of the lead, or the more uniform its quality, the less is it acted upon by the water. Lead, therefore, of different qualities should never be used to line cisterns with. The mixture of tin with lead also favours the oxidising influence, hence it is that the lines of junction of the sheets of lead, where the solder is used, are always the first to give way under the corroding action. But while the same water is thus seen—or at all events is believed, for the point has not actually been decided—to act upon different qualities of lead, different qualities of water act in different ways upon lead. Thus, soft water acts much more quickly upon lead than hard, more especially if organic impurities are present, as they often are present, in open lead-lined rain-water cisterns, where leaves, or small branches of trees, are blown or drop into them. But while soft water—and rain water is the softest of all—acts more quickly upon lead than hard water, this difference in the result of the action is specially worthy of notice—namely, that the hydrated oxide of lead formed by the action of soft water upon the lead lining of the vessel in which it may be stored up, is insoluble, or merely suspended in the water, so that it can easily be remedied by means of filtration, and in water allowed to remain quiescent it subsides to the bottom. But water containing mineral substances, such as carbonate of lime, or alkaline substances, such as carbonate of potash or of soda, and therefore known as hard water, while acting upon lead much less quickly and decidedly than soft or rain water, yields a hydrated oxide of lead which is soluble, and therefore combining chemically with the water, cannot be removed by filtration. Hence it is safer to trust to the use of soft water than to that of hard, where its action upon lead is dreaded.

The presence of organic matter in water, whether arising from decaying vegetable matter allowed to get in and to remain in it, or from coming in contact with sewage-soaked soil, or from the flowing of sewage matter into the well or cistern, has, as already been stated, a great influence on the action of the water upon lead in the formation of the hydrated oxide of lead. This arises from the presence of nitrous acid from the decomposition of the organic matter. Dr Medlock has shown that these nitrates can be, however, neutralised by simply placing in the water coils of iron wire or sheets of iron.

If lead, then, as a material for lining water cisterns be rejected, the question is, what material is the best to be used? In country districts, where the cistern is generally outside the house, and plenty of space can be given to it, stone or slate give the best material; and of these slate is the best, as stone is found to be apt to favour the growth of the green confervæ or weeds, and the softer the stone the more freely are the confervæ developed on its surface. Slate slabs are now easily obtained of any dimensions required, and a good cistern can be formed with them at moderate expense. But both slate and stone are bulky and heavy materials, and are, therefore, not suitable, or not so suitable, for cisterns placed in the interior of houses. Other substitutes must, therefore, be found. Zinc has been recommended as a good material for the lining of cisterns, but, although very light, it is in fact more easily acted upon by water than lead. Galvanised iron has also been much used, but recent investigations show pretty conclusively that the zinc present in the galvanised covering of the iron is also quickly attacked by water, especially water in which air and saline substances are present. Taking all points into consideration, we are inclined to recommend wrought-iron cisterns as the best; and they are now being rapidly introduced into use. They are light, cheap, and, when well painted, last a long time. We would, however, recommend the insides of these cisterns to be coated with the tar composition now used so successfully for the lining of the large cast-iron pipes conveying town supplies of water.

Seeing the action of water upon the lead lining of cisterns, objection has naturally been made to the use of lead service pipes. But the same objection does not obtain in their instance. The water as a rule does not remain long in contact with the lead service pipe, as it is very frequently withdrawn for use; and as we have already pointed out, the action of water upon lead is generally hastened by the alternate dryness and moisture to which lead in cisterns is subjected. This does not obtain in the case of pipes which as a rule are kept always full. But, as prevention is better than cure, lead service pipes are now made lined with tin. Fig. 46 illustrates a section of a pipe of this kind as manufactured on Haine's patent. The dark line indicates the position of the tin lining, which in fact forms an interior pipe of tin, incased within one of lead. The process of manufacture is such that there is a close connection formed between the tin and the lead. These pipes can be worked and used with as much facility as lead pipes. They are much lighter—a pipe of $\frac{3}{4}$ inch bore weighing $2\frac{1}{4}$ lb. to the foot, a lead pipe of the same bore weighing $4\frac{1}{2}$ lb.—thus the saving of the lead pays the cost of the process of making, so that the new pipes are just as cheap as lead ones.

Fig. 46.



But as in other departments of sanitary science, so in this, there is considerable diversity of opinion met with. Thus, while we have taken occasion to point out the value of soft water for the majority of our domestic purposes, and while showing, as we now have attempted to show, that soft water is not so dangerous—when affected by lead—as it is generally supposed to be, there are others who hold the opposite opinion. Thus we find those who strongly advocate the use of hard water in preference to soft, and while regretting that space does not permit of our going into a full discussion of the points involved in the question, we think it right to give the following extract from an article recently published in one of our scientific journals, and which conveys the pith of what has been said in favour of hard as against soft water :

"The strongest point in favour of soft water is that it saves soap. No doubt this is a recommendation in large manufacturing towns, and the advocates of this description of water calculate the saving in Glasgow from this item alone at something enormous. These statements must be received cautiously, particularly when it is borne in mind that the calculation is rather an abstruse one to arrive at, even approximately. The report to which we have alluded proves that, except on economical principles, there is no advantage gained by employing soft water in many of the manufactories, and refutes the argument by showing that the great firms in Lyons, Amiens, Rheims, Rouen, always use hard water, and, what is more to the point, maintain that by its aid a degree of brilliancy of colour is imparted to their products, which they would not possess were soft water employed instead. The deleterious action of soft water upon leaden pipes is too well known to require comment, and, as a rule, this description of water is far more susceptible of contamination than the other. It absorbs gases more readily, assimilates organic matter with greater facility, and is more liable to become unfit for use after being preserved in cisterns and reservoirs for any length of time. The Thames water may be circulated through leaden pipes or kept in leaden cisterns with complete safety. It is true that water cisterns in London are corroded, but this is due to the mud, which subsides to the bottom, and there is no appreciable dissolution of lead in the water, which is the chief thing to be afraid of. As the process of boiling is a species of purification for every kind of water, we should be inclined to give the preference to hard water for the purposes of drinking, either soft or hard for the kitchen, and soft for washing."

We now take up the consideration of the other way in which water, otherwise pure and healthy, may be contaminated by being mixed with the organic matter from sewage, or from passing over or in contact with decaying organic matter, as graveyards, decomposing matter of cesspools, privies, or from the organic matter derived from the decay of vegetable or animal organisms met with in certain waters, derived from lakes, reservoirs, or the like, or often found in river water. And from the evidence of scientific research into this source of water contamination, as well as from reasoning from analogy, we are inclined to think that the unwholesomeness of water is much more dependent upon these sources of contamination than upon the saline substances found in it, and which we have already pointed out. Scientific opinion is fast becoming general in favour of this view, although—from what we have had occasion more than once to note, as to the diversity of opinion held in all the departments of sanitary science—the reader will be prepared to learn that there are those who think otherwise.

As forming really the most obvious, if not the most dangerous, source of contaminated water supply, we take up the case of springs, streams, or rivers into which supplies more or less great of house or town sewage are sent, and from which water is taken for household purposes. We could cite numerous cases in proof of the evils arising from this condition of matters, but we select the following indicative of general results in similar cases :

" In the upper part of a city there was a severe outbreak of dysentery and typhoid fever. A physician called to attend to some of the cases, set to work to find out the cause. On inquiry as to the water supply, he was directed to a spring on low ground in the midst of the settlement, so situated as to receive the surface drainage. The water was pure and sparkling to the sight and the taste, and was loudly praised by the owner of the spring. A quantity put in a bottle and allowed to stand a few hours, threw down a thick sediment of most offensive matter, which, on being tested, was found to be as purely excrement as if it had been taken from a privy.

The people ceased to use this water, and the epidemic ceased at once."

"In a neighbouring village," says an American writer, "typhoid fever broke out, and prevailed with great violence in a given locality. Search was made for the cause by the attending physician, but in vain. They appealed for aid to the health authorities of New York, and an expert officer examined the history of the outbreak and the locality, and predicted that a certain hydrant, which supplied the victims with drinking water, communicated at some point with house drains or the street sewer. The water-pipe was examined, and at a distance from the hydrant a house drain was found leading into it at a point where they traversed each other. The repair of these pipes was the cure of the endemic.

"While visiting in an interior township of this State, famous for healthfulness and the beauty of its scenery, I became interested in the history of a family which was suffering from typhoid fever. Of eight members, five had perished, and one was then fatally sick. On visiting the locality, the house was found situated on an elevation, and all its surroundings were admirably arranged for health. One could readily believe the statement that there had not been a case of sickness in the house for twelve years. The following history of the present sickness was given: A few weeks before the fever appeared, the pump in the well broke, and the farmer being driven with his work, neglected to have it repaired. Meantime the servant brought the water from a spring at the foot of the hill, which soon became low, owing to the drought. He then resorted to a small brook, and from this source the family were supplied for two or three weeks. This stream higher up ran through several farm yards, and received the surface drainage. The first symptoms of poison by this water was slight nausea and a mild diarrhœa. After several days, typhoid fever, in its worst form, was ushered in. Of the entire family, but two escaped an attack, and they did not use the water. An examination of this water revealed a sediment of excremental matters."

Little indeed is, we think, necessary to prove that water having mixed with it organic matter of a highly offensive kind cannot be healthy, and in view of the evils arising from this cause, more or less decided according to circumstances, it is of high importance that some method should be at command by which to ascertain whether a water is really rendered impure from the presence in it of organic matters; and if so, to what extent. The importance of this led the Registrar-General to ask Dr Frankland, the eminent chemist, to investigate the subject, and the result of his labours in connection with it was the discovery of an analytical method, by which the fitness of a water for domestic purposes could be ascertained. The following, from "Engineering," is an account of this method:

"Directing his attention chiefly to the amount and nature of the dissolved organic substance, to the consideration of which it has long been perceived that the question of wholesomeness is limited, he (Dr Frankland) first ascertained, and proved, that the results obtained by methods then in use were either defective or erroneous, and, in reality, afforded only an increased facility for guessing whether water was wholesome or not. To meet his difficulty, Professor Frankland devised a plan by which carbon and nitrogen, the two most important constituents of the organic substance in water, could be determined, and, guided by the fact that, so far as the nitrogenous animal substances introduced into water by sewage contamination might remain undecomposed, they were most likely to communicate unwholesome characters, he made those determinations the basis for judging as to the quality of water. He also supplemented that plan by a determination of the nitrogen present in the water as nitrites, nitrates, and ammonia; for, since those are the products into which the nitrogenous animal substances in sewage are converted by the self-purifying action of the flowing water with which it is diluted in a river, their amount would indicate the extent to which the purification had advanced. By this means four results were obtained; in the first place, the total amount of combined nitrogen in the water would indicate to some extent, the original sewage contamination, when the amount of combined nitrogen in sewage was taken into account. Of that total amount of nitrogen, the portion existing in undecomposed organic substance would be a measure of the sewage admixture which had not undergone conversion into products of a harmless nature, and it would serve to indicate the relative degrees of purity and wholesomeness of the water. If the amount of this organic nitrogen in water did not exceed $\frac{1}{30}$th of a grain per gallon, corresponding to an unaltered sewage contamination of about ·5 per cent., such a result might be disregarded as being little above the average amount of experimental error; but in the event of larger amounts of organic nitrogen being found, there would be good reason for suspecting the quality of the water. A further indication of the degree of purity is furnished by ascertaining the amount of ammonia, which is a product of putrefactive decomposition of the animal substances in sewage, and in water of good quality this should not amount to more than about $\frac{1}{500}$th of a grain per gallon. The estimation of the nitrogen existing in the state of nitrites and nitrates does not afford any direct indication as to the quality of water, but it is useful chiefly in revealing the probable history of the water, and the extent to which the nitrogenous animal substances of the sewage or manure, with which it may have been previously contaminated, have undergone conversion into those harmless products. At the same time, if the presence of a very large amount of nitrogen in this form indicates a considerable previous sewage or manure contamination, amounting, say, to 5 per cent. or more, there is then reason to suspect the quality of the water, since there would be a possibility that some of the deleterious contents of the sewage admixture might still remain in the water, and be capable of causing mischief. If, at the same time, the water contained much organic nitrogen, there would be ample reason for declaring it unfit for dietetic use. Apart from certain minutiæ in the shape of corrections to allow for ammonia, nitrites and nitrates originating from rain water, these are the chief features of Dr Frankland's method of determining the quality of water, and it is beyond question the only one yet devised that has been tested on any considerable scale, and that has been found capable of indicating, with any claim to scientific precision, the history and actual condition of water intended for domestic use."

Dr Stevenson Macadam, the well-known chemist of Edinburgh, who has paid great attention to the water question, states that "the line must be distinctly drawn between non-putrescent organic matter and that which is putrescent. Marshy places impregnate water with putrescent matter, and hence marshy waters do not belong to the same class as peaty waters. There is a decided difference in the relative properties of the gases dissolved in such. Animal impregnations from sewage or highly manured fields form the most dreaded contamination, and yield waters which, though clear and sparkling, and cooling and refreshing, are yet most unwholesome and deadly. The quantity of non-putrescent organic matter in the present Edinburgh, the South Esk, the Heriot, and the St Mary's Loch waters, is close on two-thirds of a grain in the gallon, and there is practically no difference between them. The gases dissolved in waters form one of the best guides as to the quality of the water. The carbonic acid varies in quantity according to the hardness of the water, when such is due to carbonate of lime (chalk), and the proportions of oxygen and nitrogen should be nearly as 1 to 2. Where putrescent matter is found in waters, the proportion of oxygen decreases to 1 to 3 or less, and such indicates positively unwholesome qualities in the water. The vegetable and animal life found in all wholesome waters is the same. In all natural and artificial reservoirs fresh water algæ are found adhering to the stones in the quiescent parts, and where the stones do not roll over each other. Every Highland or lowland loch, and every pond in the Pentland Hills, is an illustration. Take Loch Katrine or Loch Lomond, Loch Lubnaig or Loch Earn, Loch Venachar or Loch Achray, Lochs Menteith, Chon, or Ard, and the Pentland ponds, especially Loganlea, Glencorse, Clubbiedean, and Torduff, and in even comparatively sheltered spots, the stones are covered with the same vegetable algæ. Similarly, in St Mary's Loch, where at the north side the algæ may be observed, whilst at the east and south sides, where rolled pebbles are prevalent, little vegetable growth is noticed. The same algæ cover the stones in the more quiet-running parts of streams, and are not found in the streams where the current is greater. These fresh-water algæ are more evidence of the purity of the water than of impurity. The animal life visible in fresh waters consists mainly of minute organisms about the size of a pin-head—minute crustaceans, principally Daphnia pulex and Cyclops quadricornis. At the sides of all lochs and reservoirs you can pick up larvæ of insects, water-scorpions, and other animal forms, which live *in-shore;* but the so-called water-fleas are denizens of the water, and are found in all lochs and cisterns which contain fresh, wholesome water. They are also present in the more quiet-running parts of streams. They are never found in waters containing putrescent matter. The cyclops is the true common flea, and during the warmer months is found very abundant in every pond in the Pentland Hills, as well as in smaller numbers in Loch Katrine, Loch Lomond, and St Mary's Loch. The daphnia keeps nearer the shore, and is found most abundant where the fresh-water algæ grow most luxuriantly, as on the embankment at Clubbiedean. The living vegetable organic matter apparently forms good feeding ground for them. The fleas are very delicate organisms—a small amount of alcohol added to the water kills them at once, a temperature of 100° Fahr. is equally destructive, and any decrease in the proportion of oxygen dissolved in the water, at once causes their death. The insertion, for a few hours, of a cork or stopper in a bottle containing water with fleas is sufficient to stifle them. They can only live in thoroughly aerated and pure waters; and when partaken of in water, it is impossible they can live in the animal system."

The investigations recently made by Dr Frankland seem to us of the utmost possible importance, for they point not merely to the contamination of water arising from "putrescible" matter in it, but to other sources of contamination not at one time ever dreamed of as existing, and of which even yet we do not know much. Enough is known, however, concerning them to lead us to the conclusion that we have yet much to learn in connection with the "water question." What these recently discovered, or presumably discovered, sources of contamination are we shall presently notice, meanwhile offering a few further remarks upon the subject of sewage contamination. Dr Frankland maintains that water once contaminated with sewage matter, even if purified subsequently by filtration in the most perfect way attainable, if not positively dangerous, is "still unsafe" to be used. Dr Odling, another eminent chemist, on the other hand, holds views exactly the reverse of those of Dr Frankland. He says: "After a large practical acquaintance with the subject as it is observed in the principal streams and rivers of England, I have arrived at a very decided conclusion that sewage, when it is mixed with about twenty times its volume of running water, and has flowed a distance of ten or twelve miles, is absolutely destroyed, the agents of destruction being infusorial animals, aquatic plants and fish, and chemical oxidation." He founds this opinion on "many considerations, and especially from the fact that the undefecated sewage, etc., discharged into the Thames above the source of the present water supply, is not recognisable in the water at present supplied."

So far as the "infusorial" agents are concerned as tending to purify the water—which Dr Odling maintains they do—in which sewage has been present, a well-known authority puts the matter very suggestively thus—

"The sewage being destroyed, are the 'infusorial animals' destroyed also? Reasoning by induction, we have every reason to believe that animal organisms exist outside the range of microscopic vision. Dr Letheby (who agrees with Dr Odling in his view of the question) may see nothing, and yet something may exist—something which lives and possesses powers antagonistic to human life. There are animal organisms so minute, that to them the pores in a piece of chalk are like the tunnels in a hill side to a railway train. By their minuteness they defy filtration, and such is their tenacity of life that certain species will outlive the process of boiling. The futility of filtration is shown by actual experiment, performed by Dr Frankland. One volume of the rice-water evacuations of a cholera patient was mixed with 500 volumes of distilled water. Dr Letheby would apparently be satisfied with a twentyfold admixture of ordinary water. It is true that Dr Frankland did not send the mixture running for 'a distance of ten or twelve miles.' But he did something else. In the first place, he passed the mixture through filter paper. Before its filtration the liquid was opalescent, and so it remained afterwards. In this state 100,000 parts of the filtered liquid, when submitted to the action of potassic permanganate, required ·0430 part of oxygen for the oxidation of the organic matter contained therein. The average amount of oxygen required to oxidise the organic matter contained in 100,000 parts of filtered Thames water, as supplied to the metropolis, is ·0724 part. Thus, according to the potassic permanganate test, the diluted rice water was far purer as regards organic matter than the water ordinarily drunk by the inhabitants of the metropolis. 'In fact,' says Dr Frankland, in his report of these experiments, 'it may be safely asserted that the addition of cholera rice water to the water of the Thames, in the proportion of 1 to 1000, would not materially affect the results of a chemical analysis of the water.' In the next place, Dr Frankland took the filtered liquid, and passed it rapidly through animal charcoal. The opalescence was thereby further diminished, but not entirely removed. The organic matter still remaining in 100,000 parts required only ·0103 part of oxygen for its oxidation. Dr Frankland sums up by saying: 'The foregoing experiments show, first, that water may become seriously contaminated with choleraic matter, without the presence of the latter being indicated by chemical analysis; and secondly, that water so contaminated is not completely deprived of this impurity either by filtration or passage through animal charcoal.' Experiments by Professor Thiersch and Dr Saunderson show that paper saturated in cholera flux, and dried, when eaten, produces the disease in a transmissible form in mice. 'The fresh flux the first day after exposure in the air is almost inert, on the second day it grows more active, on the third it is at its maximum of activity, is less and less active on the fourth and fifth, and becomes inert on the sixth day of transformation.' Of 148 mice experimented on, 95 showed no symptoms, 53 were affected, and of the latter 31 died. It is remarkable that on a second occasion, when the thermometer had fallen from 56° to 49°, the experiments failed. One circumstance which increases the danger is the law observed by cholera, in common with other zymotic diseases, whereby the mildest type is capable of communicating the disease in its most malignant form. Thus the most virulent cholera matter is producible from patients who are seemingly only attacked with diarrhœa. Experience also shows that water poisoned by sewage is capable of propagating cholera, even though the water be boiled and drunk in the form of tea. Cholera flux is of low specific gravity, and sinks very slowly in water. Dr Hassall describes the deposit, when seen under the microscope, as consisting of 'innumerable mucous corpuscles, globules of oil, and myriads of vibrions.' Pacini has found that the germs of vibrions are less than the 25,000th of an inch in diameter; so that, if heaped in a mass, there would be as many as 15,625,000,000,000 germs in a cubic inch. 'Allowing for interspaces,' says Dr Farr, 'it is evident that a cubic inch might hold millions of cholera particles, and one cholera patient might disseminate in water millions of millions of zymotic molecules.' Dr Farr notes an essential difference between zymotic venom and a metallic poison like arsenic. The former varies in its power from day to day, while the latter remains the same. The infection power of the cholera liquid grows and declines by a law of its own; and the water which on one day is poisonous, may a few days afterwards be harmless. Such is the nature of the influence which may be said to threaten the water supply of the Thames. The analysis of the London waters shows the presence of nitrates, and we cannot be assured that animal organisms of a dangerous type will not sometimes accompany these compounds. Farmyard manure, as well as town sewage, if applied in excess, is capable of so impregnating the land that its drainage shall affect the river. Clearly the utmost care ought to be taken to exclude impure fluids and other offensive matter from the Thames."

And what is true of the Thames is equally true of every river and stream under similar circumstances. Certainly, taking all things into consideration, it appears to be unmistakably a wrong thing to draw the supply of water for house consumption from rivers, or any other source of supply into which sewage matters are passed, and while or shortly after these matters are fresh, or in a highly putrescible condition. And so far as taking a supply from these rivers at a point a considerable distance down from that at which the sewage matters have been delivered is concerned, although the purifying influences, which Dr Odling names, may be as powerful as he believes them to be, still, in view of the fact that other authorities hold views opposed to his; and in view further of this, that, in reality the points involved are by no means settled conclusively, and the inference, which may be fairly drawn, that poisonous matters once put into water must always be so far present as to be a source of danger more or less active, but still to a certain point active—it appears to be the best thing to err, if one is to err at all, on the side of safety, and not partake habitually of waters which have once contained sewage, however pure they may appear to the eye, and however agreeable they may be to the palate. Microscopic observation of water, supposed to contain organic impurities, has been successfully adopted by Dr Hassall. The occurrence of the vegetable species and animalculæ is, he says, an infallible proof of the presence of organic impurity in its worst stage—that is, in the act of putrid decomposition, or in the course towards this consummation. These plants and animals feed upon the remains of other plants and animals, and cannot subsist upon the remains of mineral water alone. A water is not perfectly pure if a single living being can live and procreate in it, and in proportion to the abundance of life is the amount of impurity. The stagnant pond overgrown with grass, slimy vegetation, and swarming with insect life, and with innumerable microscopic animalculæ, gives the highest possible evidence of its pollution. "It is a fact worth noticing," says this authority, "that particular species of creatures belong only to certain degrees and circumstances of pollution; so that the occurrence of a single specimen of such species stamps the character of a water at once. One species of the paramecium he designates as the Thames paramecium, because he found it in all the waters derived from the Thames in the immediate neighbourhood of London." In testing water by the microscope, particular reference must "be had to the season, temperature, and other circumstances favouring the growth of river beings. If waters are to be compared with one another on the point of organic pollution, they must be examined under nearly the same conditions. The months of July, August, and September, present the animalculæ activity in greatest force, and during these months the examination by microscope should be made. A water may show no living beings in the winter, and yet be far from pure; while, on the other hand, some streams, like the Thames, contain life all the year round, and differ in different seasons only in the number of species and of individuals. The microscope is also available in testing water, the taint of which may be supposed to be produced from intermixture with sewage matters. The solid particles may be easily identified with those of the decomposing remains in the sewage water. Dr Hassall detected the presence of sewage matter in the London waters by this means. A very simple method of testing the presence of organic impurities in water has been recommended by Mr Homersham · "Fill a stoppered bottle nearly full of the water, and put it aside in some dark place, where it will experience a temperature of nearly 70° Fahr. After allowing it to stand a few weeks, draw the stopper, and apply the nose to the mouth of the bottle. If the water smells in any perceptible degree, it may be pronounced a tainted water." A quicker and more accurate test is that generally employed, namely, evaporating the water to "dryness," and, weighing the solid matter thus obtained, it is then subjected to a red heat, which entirely consumes all organic matter which the given quantity of water operated upon contained. Thus, suppose the solid matter obtained from the evaporation of a gallon of water amounted to sixteen grains, and that, after being subjected to a red heat, the residue only amounted to 11 grains, the weight of organic matter in each gallon of the water would be set down as five grains. If the organic matter thus obtained from any water is four grains, it is considered as excessive; while, if double this quantity, the impurity is very offensive. The results obtained by this method of testing are far from being generally correct, the chances of error in estimating being so very numerous. The newer tests already described, as applied by Dr Frankland, promise, if they do not actually give, more accurate and trustworthy results.

Although from what we have said as to the quality of various waters, it will be seen that considerable diversity of opinion exists on the whole subject, the views held by one authority being directly controverted by another, still sufficiently strong evidence is had that water containing organic life cannot be held to be a pure water, although much of the effects arising from the presence of this may in some, nay, in many, cases be such, that it may be quite safe to use the water for general purposes. Enough has been shown to indicate in a general way the point at which water may be said to become noxious to health.

What may be the result of passing water contaminated with sewage, or even sewage itself, through soil, in getting rid of the impurities in so complete a way as to render the water perfectly good for domestic purposes, is yet to be learned. No doubt, we know enough of the effects of soils upon water as to know that this purifies water quickly—and apparently completely—we say apparently, for although several chemists have not seldom affirmed that purification is complete, still, under the scrutiny of the more searching analyses now being made, it is to say the least doubtful, whether soils will maintain the high reputation as perfect filterers which they have enjoyed, and do enjoy, in the estimation of many even now.

This naturally leads us to offer a few remarks upon filtration as a means of purifying water. Filtration is of two kinds, chemical and mechanical, or it may be a combination of both. Mechanical agents in filters act as arresters of impurities, which are simply held in suspension in the water, as mud, and other substances. Chemical agents exercise a distinct action upon the water, bringing about a certain change, or certain changes in the water, tending to make it purer.

As to the ability of soils, above alluded to, to purify water from combined animal and vegetable impurities, Professor Way several years ago pointed out that various animal and vegetable solutions, such as stinking cows' urine, sewer water, putrid human urine, passed through various beds of soil, were entirely deprived of smell and taste, except an earthy smell, derived from the soil. These solutions were highly offensive, and coloured, yet the liquid dropped from the filtering soil "so colourless and inoffensive that it might be even tasted without disgust. It was in fact a mere solution of various salts of lime." It may be worthy of notice that this deodorising process can be effected without incurring the trouble of filtration, by merely stirring up the liquid and the soil together; when the latter subsides, the solution will be found devoid of colour and smell.

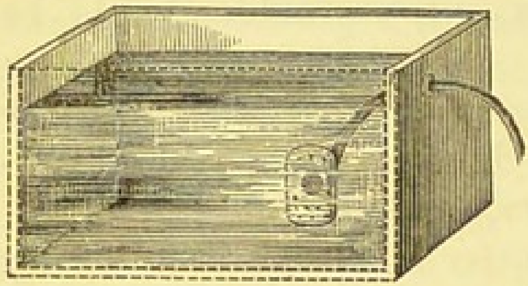
Charcoals act both mechanically and chemically, chiefly in the latter way. Of the two kinds of charcoal used, animal and vegetable, animal is by far the most powerful. When used to filter urine, the result has been a perfectly colourless fluid, quite free from smell; while the same urine passed through vegetable charcoal had left in it a slight tinge of colour and a slight smell. But where animal charcoal cannot be obtained, vegetable should be used in preference to none.

" Dr Letheby says animal charcoal possesses the power of bringing the oxygen dissolved in the water into chemical union with organic matter, and so destroying it, especially when the organic matter is in a state of decay and in an unwholesome condition. A certain time is required to allow the water to remain in contact with the charcoal; it must be in contact for a minute at least. A cubic foot of animal charcoal weighs from 50 to 52 lbs., and holds within its pores four gallons of water; and, therefore, allowing one minute for contact, water could not be filtered through it at a greater rate than four gallons per minute per cubic foot. The thickness of the charcoal bed is of little moment; it is the quantity of charcoal to the quantity of water that is to be considered. It is found that water cannot be forced through a filter containing 80 lbs. of animal charcoal, so as to be effectually purified, at a greater rate than 400 gallons a day, whereby the water is in contact with the charcoal, on the average, during a working day, for six or seven minutes.

For house cisterns animal charcoal is very valuable, and is a safeguard against the presence of organic impurities in water. Dr Frankland agrees with Dr Letheby as to animal charcoal, but says that vegetable charcoal is inert in its action on organic matter."

The majority of the numerous varieties of filters offered for domestic use are formed chiefly with layers of animal charcoal. Perhaps the best form is that introduced by the London and General Water Purifying Company, 157 Strand, London, in which the charcoal is used in the solid form designated by the patentee as "silicated carbon." The mode of using the filtering substance is, we think, very ingenious, and consists, as shown in Fig. 47, in placing the filter inside the source of supply—the cistern—and so arranging it that every drop of water must be purified before it is drawn for use. "The system adopted is shown in the annexed cut; it is the Danchell filter, which is filled with animal charcoal, and operates by ascending currents. By this means the suspended impurities are separately precipitated outside the filter, whilst those only which are held in solution pass into the filtering medium. The water becomes purified from these latter in the act of ascension through the animal charcoal. By this arrangement it will be seen that the mechanical impurities, which would otherwise clog the filtering material, are not allowed to enter the apparatus, a point of very great importance in connection with its durability. The system further affords the greatest facility for removing those impurities which are held in solution in the water, and which are intercepted within the filter."

Fig. 47.



Wool acts purely as a mechanically arresting agent, the great advantage it possesses being the retention of its porosity for a great length of time, even when highly impure water is passed through it. The same remark applies to sponge, which is used sometimes as a filtering medium, and to layers of flannel, although in a modified degree. The speed with which filtration is carried on is a matter of some importance. On this point it may be noted that the best mechanical filtering media act the slowest, the worst the quickest. Sand as a filtering substance acts both mechanically and chemically. It is to Dr Angus Smith that we owe the discovery that sand acts as a chemical as well as a mechanical purifier of water. "Its power chemically," he says, "is really very great." Sand acts chemically upon water which contains much organic impurity by forming nitrates, to which we have already drawn attention, and arresting them, so that they can be removed. Sand as a filter is powerful only in proportion to its bulk or cubical contents; a goodly quantity of it is therefore required if used alone. It is of importance to have the sand itself, which is used as a filtering material, free from impurities; for although some sand is clean—that is, free from organic impurities—other sands have much impurity present in their bulk. Sand of inferior quality may be rendered fit for use in filters by washing it, as thus: "Fill a bucket about three parts full of the purest water you can obtain, add a sufficient quantity of the sand to be cleaned till the water is raised to the edge of the bucket. Stir the whole well together, and let it thereafter remain quiescent for a few minutes. After subsidence of the sand, pour off the water. Repeat the process till the water comes off quite clear. Sand is best used in filters where the course of the water is downwards."

We now come to the second point of importance in connection with the water question, named in the introductory remarks at the beginning of this present chapter

—namely, that the supply should be abundant. A great deal has been written upon this point, but it appears to be pretty generally conceded that the minimum quantity per head of the population per day should be twenty-five gallons, although by some this is held to be quite insufficient, and who maintain that double the quantity should be allowed. In Glasgow, which may be taken as a fair type of a city well supplied with water, the number of gallons sent into the city per head per day is 54; but from this have to be deducted four millions of gallons used by various trades, leaving for domestic purposes and for waste 45 gallons per head per day. The words here used, "and for waste," indicate a very suggestive circumstance in connection with the water supply of towns, and the allowance made for it shows on examination that the quantity of water really required per day by each individual would be greatly less than even 25 gallons if no water was wasted. But in all towns the quantity of water wasted is greater than that used; at all events authorities put the amounts down as equal. In Glasgow, for example, out of a supply of twenty-three millions of gallons, no fewer than eleven millions are wasted.

No doubt there is this to be said in favour of waste, or rather that the excess of supply over what the inhabitants absolutely require for domestic purposes is not waste at all, but that it serves a useful purpose in being sent into the drains and sewers, tending to cleanse them from accumulating poisonous matter. The truth of this statement we shall see when we take up the subject of drainage and sewage in the succeeding chapter. Meanwhile, be it true or not, the point is abundantly evident to those who are at all acquainted with the habits of the people, especially of the poorer classes, that a vast quantity of water is absolutely wasted, that is, not used for the purposes for which it is supplied. Much of the power to waste is given by the, in many instances, defective way in which water appliances, as cisterns, taps, etc., are constructed and arranged ; and much has to be done in this department of house construction before it can be said that all its details are characterised by care and efficiency. Waste may in great measure be prevented by the accuracy with which taps, hydrants, etc., are made, so as to admit of no leakage, and to ensure their keeping in repair for long terms. There are also appliances which can be attached to cisterns, and taps at the sink, by which waste can be greatly prevented. The following is a brief description of a "water-waste preventor," as applied to a cistern, which is divided into two compartments—"a larger one into which the water is received, and from which it is shut off when full by the rising of a floating ball at the end of a lever, and a smaller one into which water is admitted from the larger compartment, the two plugs closing the outlets being so connected that both outlets cannot be opened at the same time, but that when one is opened the other is by the same motion closed, so that a continuous flow of water through the cistern cannot take place."

Waste may also be prevented—or at least people may be coerced into being more careful about the matter of waste—by consumers having to pay for all the water they have to use. In this case the supply is measured by means of water meters. These are of two kinds, "the one, those which measure positively, and the other those which measure inferentially. The positive water meters measure by the cylinder full, the piston which is driven by the pressure of water through the fixed length of the cylinder registering each stroke as being the quantity of water displaced by its motion. The inferential meter is on the principle of a Barker's mill—that is to say, the revolution of a spindle is caused by the unbalanced pressure of water within radial tubes which have holes on one side only, the pressure due to the area of the hole being transferred to the opposite side of the tube, causing it to recede from the direction of the hole with the velocity due to the head of water and area of orifice. To bring this principle into a practicable shape, the water passes down a funnel and outwards through curved arms, the areas of whose outlets are proportioned to the quantity of water to be registered at each revolution, and inasmuch as the number of revolutions would increase with the pressure of water, and therefore register more water under great than under small pressures, vanes are attached which, by meeting with a greater resistance under a rapid than under a slow velocity, retard the motion in the same ratio as the greater head of water tends to increase it, thus registering the same quantity under all pressures. By these means, and by minute attention to the perfection of manufacture of every part of the machine, great accuracy is attained; the meters are, indeed, guaranteed to register accurately within 5 per cent."

It is to be regretted that in many towns where water meters have been supplied to consumers, that grievous complaints have been made by them as to the inaccuracy of registration secured by certain meters, inaccuracy leading to grave doubts as to whether charge was not being made for water which had never been supplied to the consumer. This may have arisen from defects either in the apparatus or in the inaccuracy with which its parts were made and put together. And it is only right to state that, in the opinion of some mechanics, a water meter really trustworthy in its indications has yet to be invented; that some of those introduced into practice are far from reaching the standard of perfection, are, in fact, as likely to indicate against the company supplying as against the consumer purchasing. Wasteful habits, in whatever direction, are dangerous habits, and it would be well if, to the ordinary lessons of the school, could be added some bearing upon the morality of the question involved in them. But we have, in our second chapter, offered remarks already upon this subject, while writing of the care of house property, so that we need not here further enlarge upon it.

The sources of supply of water are—first, rain water; second, spring or well water; third, river or stream; and fourth, the catch-water of hilly districts and of rural districts. We have already pointed out the value of rain water for many if not the whole of domestic purposes, and from this will be seen the importance of providing means by which the supplies obtainable may be stored up for use. The saving of rain water will obviously be carried out more easily in the case of country and suburban than in that of town houses. Nevertheless, by far the greater majority of houses present facilities more or less readily available for the intercepting and storing up of the rain water which falls on the roof. To allow it to go to waste in the case of suburban and country detached houses, is a waste for which there should be no excuse offered.

Where water, as rain water, is stored up in underground cisterns, by far the best material to use is Portland cement concrete. Of the form which may be given to the tank, the square, rectangular, or circular, the circular is the strongest, although with the use of the Portland cement concrete, the rectangular may be adopted, as the framing required to form the mould for the concrete will be more easily made than that required for a circular tank.

It will be well here to give a sentence or two as to the quantity likely to be obtained on an average from roof surfaces in suburban and rural districts, where the storing up of rain water will be a much more simple operation than in crowded towns, especially where the "flat" system, as in the north of the kingdom, is the rule. A

French writer on the subject has a theory which we are inclined to think nearly correct, that the "rainfall" of a country yields an ample supply for the wants of the inhabitants. In rural districts the "well" is the chief, and in many places the only, source of supply. This often not only runs dry, but the supply is not of good quality, being frequently subject, especially in the case of houses near farm yards, to contaminating influences. He therefore recommends the "formation of reservoirs to receive the rain water and replace the old wells. He puts a simple case as follows: Suppose a farmer has but an acre or two of land, his cottage will contain an area of roof equal to something like 90 square yards, and as the average of the downfall of rain is 76 cubic centimetres, the surface above named would produce 60 cubic metres of water per year. As regards consumption, he says: "An adult requires ten litres, or, let us call it, two gallons of water per diem, or three cubic metres a year; a horse five times that quantity, or 50 litres; horned cattle 30 litres a head; sheep two litres; and pigs three litres." He supposes the farm house to be occupied by a man and his wife and two children, and the live stock to consist of one horse, one pig, and one cow. According to the previous statement, the wants of the little establishment would only amount to 44¼ cubic metres per annum, and a reservoir 46 metres square and four metres deep would, he argues, be even larger than required. After the first expense, the farmer, he says, would be put to no expense but that of maintaining the roof of his cistern and the conduits leading to it."

The following is given as a rule for estimating the quantity of water obtainable from the roof surface of a house. If the rainfall averages 25 inches per year, this gives rather "more than two cubical feet for every square foot of horizontal surface employed in catching it, or say 200 cubical feet of water to the square. Each foot contains $6\frac{1}{2}$ gallons of water. A tank 15 feet × 9 feet × $7\frac{1}{2}$ feet will hold 6581 gallons, and about $5\frac{1}{4}$ squares of horizontal surface would catch enough rain water to fill it in the year at the above rate of rainfall. In estimating the area of roof, the level area only must be calculated, and not the surface area, which is often half as much again. Hence the simple method is to take the area of ground plan and double the number of feet contained in it, which will give the amount in cubical feet of water that on the average may be collected in each year."

Spring water is derived from two sources—first, surface springs, which well up at or near the level of the ground, and springs intercepted by a well sunk, cutting the soil or rock through which the water passes. Spring water as a rule is generally pure and of good quality. In rural districts it is rarely found contaminated with organic matter, but it may be hard from passing over certain rocks or through certain soils, or from being drawn from the chalk formation. In rural districts water is often had in great abundance and of good quality from surface springs, but it is often rendered mechanically impure by the careless way in which the water is allowed to well up, often in a mere hole in the roadside. By sinking a stone trough, or a shallow well lined with cement, water may at all times be drawn off pure, or comparatively free from suspended matter. The deposited matter which settles at the bottom may be taken out from time to time, which will tend greatly to keep up the purity of the water taken out for domestic purposes.

We have stated above, that as a rule, water obtained from wells in rural districts is generally pure, but the same cannot be said as to wells in towns. In many cases the water is greatly deteriorated in quality by the presence of organic impurities percolating through the soil, this being very markedly the case in towns where the open privy and cesspool system has been long in existence. In some towns where this has been so, as in Liverpool for example, the water in wells has become so contaminated as to be deemed unfit for use, and this has been absolutely prohibited and prevented by the closing up of all private wells.

Water is obtained in great abundance from the chalk formation, and although always more or less hard, has been always considered pure, or free from organic matter, excepting in localities notoriously infected with sewage matter. But some recent investigations have tended to throw grave doubts as to the accuracy of the views hitherto held upon the freedom, even under the most favourable circumstances, from organic matter of water obtained from the chalk formation—a freedom held as so completely established that "chalk spring water" is generally taken as if not exactly, at all events approximating most closely, to the standard of all that is excellent in a town supply. The "grave doubts" as to the accuracy of this generally held opinion, have arisen from the investigations of Dr Frankland into the quality of water supplied by one of the London water companies, and whose supplies are obtainable altogether from wells sunk in the chalk formation. From holding thus the "highest rank" as a water which was purified from the source from which it was taken, Dr Frankland shows that it holds the position of being "altogether the worst sample" of the samples supplied by the eight London water companies. The analysis made by Dr Frankland showed that this water contained a very high per centage of nitrates. The water in question is derived nearly wholly from the drainage of cultivated, and therefore manured land, and Dr Frankland is of opinion that on the supposition that the water from this percolates through the chalk, carrying with it nitrogenous matter from the manure, this is sufficient to account for the nitrates found in the water. "There is, however," says a well-known writer, "another element in the question, and that is the actual constitution of chalk itself. It is well known that sugar can be converted into butyric acid by being brought into contact with putrifying cheese. In like manner sugar can be converted into butyric acid by contact with chalk. Thus chalk acts as a ferment, and the process to which we have just referred is a strong reason for supposing that chalk contains living animal organisms. These organisms being small, beyond even the power of the microscope to detect, must exist in vast numbers. The nitrogen which enters into the substance of these creatures is probably derived from the percolating rain and manure water. Dr Frankland contends for the fact that springs which cannot be contaminated by sewage or by manure contain nitrates in so low a proportion that they fail to come near the point at which the calculation of previous sewage contamination commences. Perhaps it is impossible to find a chalk well which is so situated as to be perfectly clear of both sewage and manure, though, in the case of a deep well, this merely results in the production of nitrates which in themselves are harmless. Neither can we leave out of sight the fact that prehistoric contamination may affect the springs of water. Animal decomposition appertaining to cycles long gone by, may have left traces of its existence in the form of 'harmless and combined nitrogen.' But with regard to the presence of living organisms in the chalk, Dr Frankland says he has an objection to 'putrifying animalculæ' as well as to 'putrifying sewage.'"

It has also been suggested that another source of the nitrates found in this chalk water may have been the percolation of the sewage matter in the Thames not far distant, a source deemed by authorities not unlikely, as recent investigations have proved that sewage matters percolate much more deeply and widely through the soil than has been hitherto supposed. The whole question here involved is one of the greatest importance, as showing, as the writer above quoted says, "that water of a most dangerous character might otherwise be allowed to pass with a certificate of purity. After the sewage itself has disappeared, the virus which it has communicated to the water may remain. At any time it is not so much the sewage itself that kills, as something which accompanies the sewage. An offensive gas does not necessarily induce disease; but the bad smell indicates a state of things favourable to the propagation of poisonous germs, which, on entering the human system, are capable of producing disease—it may be cholera. The Royal Commissioners say: 'In the present state of chemical science, analysis fails to discover in properly filtered Thames water anything positively deleterious to health.' It is well to know that the very same thing might be said of sewage itself, or even of the dejections of cholera patients, although these dejections are known, by direct experiment on the lower animals, to have the power of communicating cholera."

The next source of supply to be considered is that of rivers. The quality of river water varies very much, according to the districts through which it flows, and to the impurities with which it may be contaminated. Where these impurities are merely mechanical, they are generally easily got rid of by adopting one or other of the modes of filtration which we have described. It is obvious enough that the sooner the water is taken from the surface upon which it falls the purer will be its quality—that is, the shorter time it is in contact with the soil surface, the less time will be afforded for it to take up matters existing in the soil which may be of a more or less prejudicial character. Thus the water proceeding from or flowing through peaty soils will be more or less impregnated with the vegetable organic matter with which these soils abound, in proportion to the time over which the contact of the water with it extends. River water, when derived from sources far removed from towns and villages, where sewage matters are largely met with, is generally pure; but, as will have been gathered from what we have already given, sources of contamination may arise from the nitrogenous matters carried into the river by the drainage from manured land. The following table, from a paper by Mr Baldwin Latham, will show the chemical constituents of the water derived from several rivers:

ANALYSIS OF RIVER WATER.

Name of River, and authority.	Carbonate of lime.	Sulphate of lime.	Carbonate of magnesia.	Sulphate of magnesia.	Chloride of magnesia.	Sulphate of soda.	Carbonate of soda.	Chloride of sodium.	Sulphate of potassa.	Nitrate of potassa.	Nitrate of soda.	Nitrate of magnesia.	Phosphates, earthy.	Alumina.	Oxide of iron.	Silicic acid.	Organic matter.	Total.
Clyde, Penny, .	2·52	·26	·72	..	·40	1·94	..	·54	1.94	..	..	..	·31	·28	Trace	·28	·89	7·86
Severn, do., .	·50	·52	..	..	·66	·39	..	·73	·39	..	..	..	·18	·32	..	·32	·45	3·75
Seine, Deville, .	11·609	1·886	·189	Trace	..	..	..	·862	·35	..	·659	·364	..	·035	·175	1·711	..	17·84
Rhine, do., .	9·511	1·03	·350	..	..	·946	..	·14	..	2·66	..	..	..	..	·406	3·423	..	16·247
Garonne, do., .	4·524	..	·238	..	..	·371	4·55	·224	·533	..	..	..	..	·175	·217	2·813	..	9·585
Loire, do., .	3·374	..	·427	..	..	·238	1·423	·336	..	..	..	..	..	·498	·385	2·848	..	9·437
Rhone, do., .	5·334	..	3·43	..	..	·519	..	·119	..	·28	·315	..	·333	..	..	1·669	..	9·082
Doubs, do., .	13·397	..	·161	..	·035	·357	..	·161	..	·287	·273	..	..	·147	·21	1·114	..	16·142
Thames, Letheby	11·10	4·78	..	..	..	·48	..	1·88	..	..	..	..	..	·76		1·0	2·75	22·75
Ouse (Ely), do.,	13·0	10·39	..	..	·37	1·01	..	2·50	..	3·40		..	..	·67		·12	1·34	32·8
Lea, ...	..	..	..	..	..	..	..	..	..	..		..	..	..		..	..	23·7
Colne, ...	..	..	..	..	..	..	..	..	..	..		..	..	..		..	..	21·3
Trent, ...	·32	21·55	5·66	..	..	..	..	17·63	..	..		..	Trace	·50		·72	3·68	50·16
Dee, ...	·85	·12	·36	..	..	..	..	·72	..	..		..	Trace	·06		·14	1·64	3·89
Don, ...	2·23	·13	1·07	..	..	..	..	1·26	..	..		..	Trace	·27		·52	3·06	8·54

River water also depends for its purity, so far as suspended matter, as muddy particles, is concerned, upon the nature of the soil forming the bed of the river, and the velocity of the stream, but impurities of this kind are easily separated by means of filtration.

The sources of contamination, however, are in the neighbourhood of towns so numerous, and in reality so dangerous, that we consider their supply of water from this source as out of the question. It may be made available in rural districts, where the village to be supplied is not very populous, but then the utmost care must be taken to draw the supply from a source above the town, so that sewage matter may not be present. Mr Bailey Denton, the well-known agricultural engineer, advocates the storing up of the drainage water of agricultural land as a source of supply for small rural villages, he holding with many others that drainage water, in place of becoming contaminated by passing through cultivated and manured land, possesses a positive superi ority over other supplies. The following, from a paper by Mr Denton, explains the mode he recommends :

" If we apply the system of storing drainage water for the supply of villages in summer, we may test the question in its monetary aspect by assuming the average population of rural villages to be 400. If each inhabitant requires 10 gallons of water per diem (a quantity quite sufficient in places where the water-closet system does not wholly prevail) it will require a supply of 480,000 gallons for the summer. This quantity is taken on the assumption that for 120 days, or four months in the year, there will not be a supply from ordinary sources. To secure this net quantity, a considerable allowance must be made for waste by evaporation, and 50 per cent. on the quantity required should be added to meet this loss. A reservoir or basin to hold 720,000 gallons will therefore be required, and this quantity of water must be stored.

"It requires very little calculation to show that if an acre of land, during the period of discharge, will yield 100,000 gallons, it requires less than 7¼ acres to yield the required quantity for 400 persons, or 12 acres of land where the soil is of the densest character. These numbers of acres would have to be increased where the rainfall is so far below the average that a minimum quantity of 10 inches cannot be depended upon during the discharging period. The reservoirs necessary to hold 720,000 gallons would be rather more than $\frac{4}{10}$ths of an acre, if the depth were taken at 7½ feet. This extent is too large for covering at a cost moderate enough for village economy, and therefore the probability is that open ponds will take the place of reservoirs, if they could be made in some convenient place above the village, and and could be shaded from the sun and protected from the wind. The expense of making the pond, using the earth to embank it, and planting the embankment so as to exclude as much as possible sun and wind, and thereby to reduce evaporation and preserve the purity of the water, would be as follows :

"Excavation and embankment, assuming that the earth thrown out formed a bank round the pond, on which trees and shrubs may be planted, 2500 yards at 6d., ...	£62	10	0
"Puddling bottom and slopes, dressing bank, and gravelling bottom 6 inches deep on the puddling, and constructing overflow from reservoir, . .	102	10	0
"Planting and fencing, ...	30	0	0
"Value of land appropriated to the purpose, three-quarters of an acre, ...	45	0	0
"Total cost of reservoir, ...	£240	0	0
"Iron pipes from reservoir, with stop-cock, well, and brickwork, ...	155	0	0
"Four stand-pipes and taps, ...	20	0	0
"Total outlay, ...	£415	0	0

"Assuming these figures to fairly represent the cost of supplying a village of 400 inhabitants with water, and the number of houses or cottages in the village to be 100, it follows that the cost per person would be £1, 0s. 9d., and the cost per house £4, 3s. If the cost were charged upon the houses, and the money were borrowed to do the work, it could be repaid by instalments, with interest in thirty years at 6¼ per cent., and the annual charge would amount to £26, or a charge upon each house of not quite 5s. 3d. per annum.*

"The capability of thus supplying villages with water is not conjectural;—every day's experience in drainage only confirms the conclusion that there are few villages in which something of the sort might not be devised. In fact, the figures given represent the worst aspect of the suggestion, for nature frequently affords opportunities of collecting the water of drainage without recourse to artificial ponds, in hollows and ready-made receptacles which may be appropriated with advantage.

"Of course, it is assumed that there are lands above the village which require drainage, and would supply the required water, and the reservoir shall be so much above the village, that by means of iron pipes, with stand-pipes and taps, the water could be delivered down the street at convenient places, for the use of the poor."

So far, therefore, as town supplies are concerned, what we have given is enough to show that they are not to be obtained either from wells or rivers. The true sources for town supplies are from the catch waters from hilly districts, these gathered by and stored up in reservoirs specially constructed in favouring valleys, or from the lakes or lochs in mountainous or hilly districts.

* Considerable objection is taken to planting round reservoirs, because leaves fall into the water and cause impurity. But when the reservoir is annually emptied and cleansed at the end of the season of supply, this objection does not apply.

"The drawback," says an authority on the water question, who otherwise advocates the use of lake or loch water, "the drawback to hill or top water districts is the presence of a trace of peat, which may communicate a yellow tinge to the water; but mere appearance should not be reckoned as of greater value than present or future unwholesomeness. Peat is certainly as abundant in the Highlands as in the Lowlands, and the peaty tinge is as decided in the Highland lochs as in the Lowland. Glasgow, Aberdeen, and Inverness are supplied with such water, and there is absolutely no proof whatever of any noxious quality being derived therefrom. Difficulties have arisen from mixing up marshy water, peaty water, and sewage-impregnated water all together. The South Esk, Heriot, Talla, and St Mary's Loch districts contain some peat on the tops of the hills, but the practical effect of such on the water is little. In all hill districts springs abound, and in the drier months of the year supply the greater part of the water running down the streams and into the lochs. The South Esk, Talla, and St Mary's districts are full of such springs. There is a slight difference in temperature between the water at the surface of lochs from that found at considerable depths. The difference may be fairly ascribed to three causes—the action of the sun's heat on the surface, the cooling influence of the ground, and the introduction of spring water. The water taken from great depths is similar in every character to that in the upper part. It is free from every noxious quality, and is thoroughly aerated. There is no reason to consider it stagnant in any sense of the term." These remarks were made in connection with the water supply to the town of Edinburgh; and it is scarcely necessary to remind those who were familiar with the discussions which took place in connection with this question, that the opinion maintained in them as to the healthfulness of such waters, was directly and most strongly taken objection to, and by eminent men of science. No case, indeed, could be more appositely cited than this same discussion connected with the water supply of Edinburgh, in corroboration of a remark we have been compelled to make at nearly every stage in our discussion of the general subject of sanitary science, that on every point nearly there is a remarkable diversity of opinion amongst scientific men. So contradictory was the evidence in this case given, that an "outsider" must necessarily have been altogether puzzled what decision to arrive at as to the value or otherwise of the water proposed to be taken into the city. Upon the whole, it appears to us, in weighing the scientific evidence on water generally, which we have detailed in the present chapter, that water without organic matter will be healthier than water with it.

We now come to the third and last point connected with the water supply question, as named in the opening remarks of the present chapter (*see* p. 138), namely, that an essential element in a good supply is that it be regular. This, however, does not necessarily imply that it should be "constant," which is another phase of the many-sided question which that of water supply is sure to be. And to this we shall presently refer, meanwhile stating, on the point of regularity of supply, that if this be not secured, manifest inconvenience will arise to parties using it, as inconvenience and large pecuniary loss will result frequently from this cause. The difficulties attendant upon securing a regular supply are no doubt partially met by the system of "cisterns" in houses, and tanks and the like in factories, in which the water can be stored up, to be drawn upon as occasion serves. But the demand for water is a varying element, and what may serve the necessities of one day, may be quite insufficient for those of another. Hence, the quantity stored up in these cisterns or tanks will be frequently found insufficient. Not seldom have we known of serious loss in industrial operations to arise from this cause; and although a fresh supply could be expected, it was not always easy to say when it would be given. Regularity in the periods in which the water was "turned on" would meet this objection, but regularity is not always a feature in the work of under-officials, and districts have been known to be without water for many hours, if not through the caprice, certainly through the neglect, of the "turnkey" in attending to his duties. Another objection to this, which has been named the "intermittent system," is that it necessitates a costly arrangement of cisterns and the attendant appliances, and as costly an attendance of the servants of the water companies, in turning off and turning on the water at the times decided upon. The gravest objection, however, to the "intermittent system," from a sanitary point of view, is that the cisterns, especially in the houses of the poorer classes, tend to render the quality of the water impure. We have already shown how this may arise from a variety of causes, such as close contiguity to water-closets, outlets from drains, and also from such impurities as the water itself may contain, and which in course of time accumulate in the cistern, and being allowed to remain there—as they are generally allowed in the large majority of cases—for a length of time, the water necessarily becomes more or less tainted. The case is aggravated in the poorer districts, where cisterns are not supplied to each house, but the supply of water being obtained from a public well or stand pipe in the court, street, or alley, it has to be stored up in open vessels and kept in the rooms. We have already shown this to be a fertile source of water contamination. These evils, and they are unquestionably grave ones, are proposed to be got rid of by employing universally the "constant supply" system. In theory this is probably the most perfect system for town supplies, it carries with it obviously so many conveniences, and gets rid so effectually of all sanitary evils attendant upon the intermittent system, that little, if anything, can be advanced against it. But in attempting to put it into practice, difficulties of no ordinary kind come up to be dealt with; and it is not easy to deal with them; so far from this, indeed, that many water companies declare decidedly that the getting rid of them in the case of crowded towns especially is absolutely impossible. Space does not permit us to go, however briefly, into the details of the question. Suffice it, that we point out in a few words what these difficulties are. The chief difficulty is undoubtedly met with when proposing to apply the system to the districts occupied by the poorer classes, and who unfortunately constitute the majority of town populations. From the very nature of the system, it is obvious that the greatest care will have to be taken to have the fittings, pipes, and taps, etc., of the best quality, and constantly maintained in perfect order, any leakage, however small in amount, representing a large loss when it is going constantly on. Hence the necessity for the water companies to have the whole system under their immediate supervision and inspection, and with full powers to exercise these at any time they deem necessary. This right to invade the privacy of the house at all times would, we fear, be greatly disliked even amongst the rich and well-to-do classes. We venture to say that it could not be carried out efficiently in the case of the poorer population; and if not done efficiently, it would be worthless. But another difficulty arises, and it is one which we fear in our time will never be overcome. The value of the fittings is such that to a very large number of the very poor the temptation to cut them off and sell them would be too strong to be resisted. This is no fancied difficulty, but one which already is in existence, and bad as it now is, it would be attended with unavoidably greater inconveniences with the supply constant; the waste would be enormous, as well as the destruction to property, arising from the rapid flow of water at high pressure. The "waste of water," which is now so justly complained of in connection with the water supply of towns, would be still greater under the constant-supply system. Again, the fittings would require to be of a much more expensive, because of a stronger, character than under the intermittent system, the pressure to which they would be subjected being much greater in the case of the "constant" supply than in that of the "intermittent" system. There are other difficulties, but those being chiefly of an engineering character, we do not further allude to them. Sufficient has been stated to show that the carrying out universally of the constant-supply system is not the easy matter some think it to be. It would be well if it could be carried out universally, but this, we fear, is not likely to be the case for some years to come.

CHAPTER VI.

TREATMENT OF TOWN REFUSE—DRAINAGE AND SEWAGE—DISPOSAL OF TOWN SEWAGE—VARIOUS SYSTEMS—PRESENT POSITION OF THE QUESTION.

In order to understand properly the whole bearings of the exceedingly important question of how best to treat and finally dispose of the refuse of our towns in their solid and liquid form, it will be necessary to glance, however briefly, at a few points in its history, these referring chiefly to the treatment of the human excreta. From a very early period in the history of civilisation, the importance would be recognised of having some means of so treating the excreta of human beings, congregated together in greater or less numbers, so as to lessen the discomforts and the evils which would be soon taken note of, as arising from their accumulation in or near dwelling places. The simplest of all modes of treatment—and the main feature of which, oddly enough, has been introduced as a novelty in very recent times—was that enforced in the Jewish dispensation, and which is described in the Pentateuch. Modifications of this, more or less simple, and which will be obvious enough on a very slight consideration of the question, would be adopted in cases where communities were small in number, and occupied localities little, if at all, crowded with dwellings. But as the population of towns increased, and certain localities became more densely crowded, such simple means would obviously be inapplicable, and others would be necessary to deal with the nuisance, which would thus be of a more obviously inconvenient character, as its results were more intensified through its concentration in confined spaces. We do not here add to "inconvenient" the word "dangerous," a conjunction of terms now readily enough admitted, while discussing the question, but which it took long years of painful experience, and no small amount of investigation and perseverance, to impress upon the public mind, as being at all connected with it in any of its bearings. These more complicated, or at all events, more systematic, attempts to deal with the excreta of our towns resulted in two modes of disposal, which may be looked upon as the ultimate results of the attempts to meet the evils, previous to the introduction of the modern system of the town tubular drainage and sewage, in which water is largely employed as the vehicle of removal. These two systems were, first, the open privy, combined with the ash-pit, or the privy singly used; and, second, the "cesspool" system, this latter being a pit into which the excrementitious matters of the household were passed from the privy or the water-closet—for this latter contrivance, as we shall see further on, was more or less used in towns long before the modern system of water-sewage was introduced—mixed, as was generally the case, with the liquid refuse of the domestic operations. These pits or cesspools were almost universally so constructed that their contents drained into, and oozed through, the surrounding soil, and too often into and mixed with the water of wells placed in close contiguity to them. The cesspools were at intervals—too long, however, as a rule—emptied and cleaned. These operations were, however, not always, if often, coincident, the "cleaning" being more a term used than an operation actually performed. The same results, more or less marked, may be said to have been attendant upon the use of the open privy, whether used singly or in combination with the ash-pit. These dangerous characteristics of the two systems for long remained unnoticed, or if noticed, uncared for; and it was only after long and patient investigations, and the persistent publication of the results of these, that the public mind became impressed with the fact that they gave rise to evils, and of the gravest character, as influencing in a very marked degree the health of those subjected to them; and that it was necessary to introduce a system more in accordance with sanitary laws. What that system now is we shall presently see.

If the reader will turn to the heading of the present chapter he will see that we use the term "drainage" and "sewage" as conveying that they are distinct subjects, in place of using them as they are almost now always used, as if they were the same. At one time they were not so, if indeed they now are, or should be treated as if they were. This will be apparent when we recollect that town drainage, when at first introduced, was meant, as it was practically carried out, only as a means of carrying off from the neighbourhood of houses the "slops" or refuse water of their domestic operations, and for the removal of rain or surface water, and the refuse of manufactories. The ultimate outlet or outflow of these refuse-water drains was the river; and so completely distinct were they considered from the system of cesspools, that in most of the towns entrance into them from the cesspools by separately made drains was prohibited either under a "positive" penalty, or practically prohibited by regulations difficult to be adhered to, or, if adhered to, only at great expense; and further, so distinctly were they cut off from connection with any system of treatment of the excreta of our population in towns, that it was penal to throw those or lead them into rivers. The result was, that as the "water-closet" became more and more used, and—as the result of an agitation on the "water question," as one of the branches of the public health—the supply of water to towns was gradually and greatly increased, the "cesspool" system became a greater difficulty than ever, and the evils—in the form of still more completely saturated soils, polluted wells and foundations, and cellars flooded with stagnant and offensive fluids—became at last so notorious that a new system became positively imperative. We have said it was long before the public became impressed with the gravity of these evils; but it is now on all hands conceded, that, in addition to the foul objects presenting themselves daily to notice, where excrementitious matter is allowed to remain decomposing in the neighbourhood of dwellings, influences of a dangerous kind are assuredly engendered, which act most prejudicially on health. The air around us, contaminated by the volatile products arising from such masses, is anything but pure and life giving. "The presence"—says the Report of the General Board of Health, on "The Sewage and Cleansing of Towns"—"of impurity produced by the decomposition of animal and vegetable matter, is now established as a constant concomitant of the excessive ravages of typhus and other epidemic diseases in towns; and a proportionate exemption from such maladies has marked the removal of the sources of aerial pollution. In proportion as perfect cleanliness has been obtained in prisons, the gaol fever has ceased to exist, and a comparative exemption from the entire class of zymotic diseases has followed the progress of purification in every description of inhabitants." Numerous cases could be cited in proof of this opinion or fact.

It is scarcely necessary to enter much further into the details of the connection between defective sewerage and the propagation of disease. It is now universally admitted, that the exhalations arising from the decaying putridity of deficiently arranged and constructed cesspools and open privies are strongly inducive of disease. Indeed, as an able authority expresses it, "the immediate and direct cause of fever" may be said to be the poison generated by the decomposition of animal and vegetable matters. The experience of every medical man goes to prove that a badly cleansed and drained district is always a fever one. A competent witness remarks, that, "in addition to a general disarrangement of health, and an unusual liability to disease, there is one particular class of disease which is always to be found in neglected places—I mean the class of contagious disorders. History teaches us that pestilence has always haunted the scenes of filth. The plague, the black death, the cholera, the camp, gaol, and ship fevers, all have made these scenes their favourite resorts; and typhus fever, our modern pestilence, forms no exception to the rule."

Another point of importance in connection with cesspools and open privies, with saturated soil, etc., surrounding them, is of great importance as bearing upon the supply of pure air to houses; for it is easy to perceive, that however well ventilated the apartments may be, the appliances are rendered futile from the admission of air tainted by the admixture of gases emanating from the filthy accumulations of the cesspools and privies. An authority, who has paid much attention to ventilation, had this view of the matter presented to him very strikingly in the course of his researches. He says that, with reference to the impairing of the health by this cause, he has no doubt that it "is one of the sources which it is absolutely necessary to remove, before there can be any effectual cure. Some of the cesspools are in the cellars, and give out their exhalations from thence; others are in a yard close to the door, which door is always open on account of the want of windows in the passage. I continually visit houses, in which the smell from the cesspool, throughout the whole of the house, is so noxious as to be unbearable; and have found the poor lodgers closely shut up in their rooms, no air being allowed to enter by the door or window, with the hope of excluding the offensive effluvia. When I have proposed to ventilate some of the rooms by means of the window ventilator, the occupants have made the well-founded objection, "we are afraid of an opening in the window, on account of the bad smell which comes from the yard." I perceived at once, that fixing a ventilator in the window, would only have been the means of introducing this noxious air."

The system introduced to meet the evils of the cesspools, was that which is now so well-known as the water-closet and sewerage one, and which brought about a complete revolution in that of the old town drains. In place of connections between the water-closets and the drains being rendered a matter of impossibility or difficulty, the connection was rendered imperative. The drains were no longer looked upon as simply means for conveying the slops of houses and the surface water off streets, but were specially made to convey, not only these, but the excrementitious matter from the houses. Formerly, they were constructed so that they were permeable, not only admitting water draining from the surrounding soil, or passing through it from the surface, to enter them, but they acted in the converse way, allowing their contents to pass from their interior and permeate to the soil surrounding them. All this was changed. From permeable, they were changed to impermeable, so that they were absolutely water-tight, as far as practically possible, in order to retain within their interior the matters which they conveyed, and to prevent as much as possible their passing out to pollute the soil by which they were surrounded. It will thus be seen that the two systems of old town drains and the new town sewers were specially distinct. In many towns the old drains still remain, being made to serve the purposes of the new system of conveying the sewage, for which, as will be seen, they are quite unfitted, giving rise to evils of a character perhaps less obvious and open to inspection, but not less dangerous than those arising from the old cesspool system.

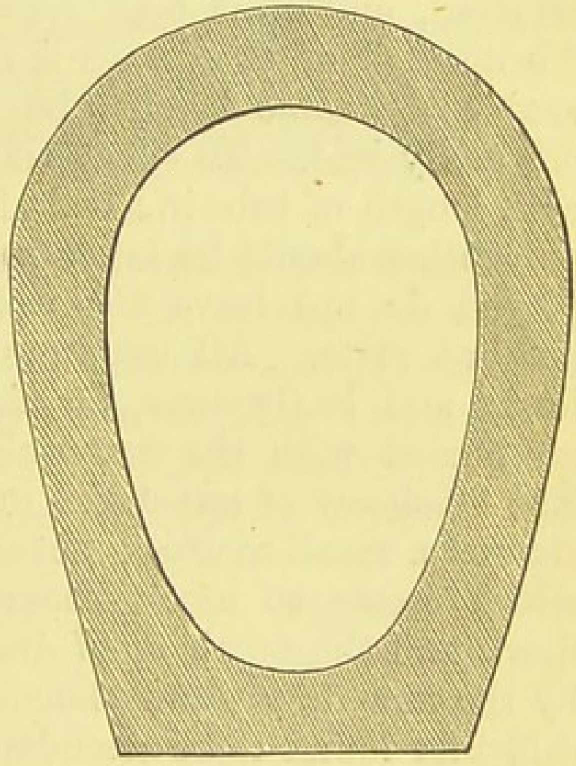
We now give, very briefly, a general view of the peculiarities and requirements of this new system of town sewerage, of which the main object is to insure as quick a withdrawal of the excrementitious matters of the house, together with the water refuse of domestic operations, and as quick a passage of the same to the place of final delivery, which, under the new system, has been, and too often now is, the nearest stream, river, or the sea. The system involves the following requirements: *First*, from the solid matter which is an invariable constituent of house sewage, it is necessary that some agent should be used to prevent this from being deposited in the interior of the drains, and which tends to block them up. *Second*, it being essential that the sewage should be delivered as quickly as possible to the place of its final deposit, the size, the shape, and the manner of laying the drains must be so arranged as to facilitate the quick removal. And, *third*, from the circumstance that the sewage matter is passed from the interior of the house, as the sink in the kitchen, water-closet, etc., apertures are there necessitated, leading directly to the drains, it is necessary, therefore, to adopt means by which the gases prevailing in the drains should not be allowed to pass into the interior of the houses through these apertures.

The condition first named is secured by using "water," without which all drains under the new system, however well laid down, will soon become inoperative.

All the water, therefore, resulting from domestic operations, as in the scullery, wash-house, water-closet, overflow of water-tanks, etc., should at once be passed to the interior of the drains. "No drains," says an authority, "can be efficient through which there do not flow currents of water. Without provision for this regular and abundant supply of water, drains not only fail in accomplishing their object, but they become positively injurious. They generate and diffuse the very poison the formation of which it is their object to prevent." To carry out this desideratum thoroughly, it is necessary that the drains should be so placed as to receive the sewage a little below the level of the surrounding ground. Hence is deduced the rule in sewage engineering, that in no case should operations be carried on requiring the use of large quantities of water, or small quantities frequently repeated, within apartments situated below the level of the ground, or below that level at which the main sewer passes. This does away, therefore, with wash-houses, sculleries, etc., in the cellars or basement apartments. The sink or slop-stone in the scullery, the tubs or washing apparatus in the wash-house, and the water-closet, should therefore all be above the above level, so as to admit of the rapid descent of the liquid sewage to the drains and sewer. The interior of the drains may be cleaned from time to time by passing quantities of water down them. This operation, known as "flushing," is very efficient. To this operation, and the influence which it has upon the water question, we shall again refer.

The new system has brought with it a great change in what may be called the engineering of sewerage, and has introduced greatly improved methods of laying down and constructing the sewers. In the old drain system, little attention was paid either to the form of the drain, or to the way in which it was made. As to the form, that generally adopted was the rectangular or square drain, with bottom flat as well as the sides. This was the very worst which could be chosen, where the object was the getting of the contents to flow through and out of the drains as quickly as possible; and further, to ensure the solid matter being carried off, and to prevent their accumulation in the interior of the drains. The diagram in Fig. 48, illustrates the improved form of sewers now largely used, and which secures the quick flow of the sewage matter through it, and the least amount of solid deposit.

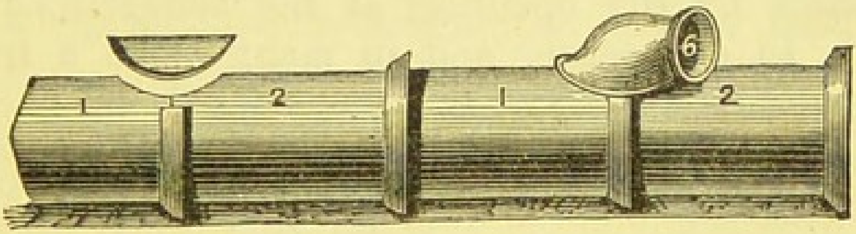
Fig. 48.



The drains leading from the houses to the large sewers which are placed in the streets are now made of earthenware, and, according to their dimensions, are either of section known as "egg shaped," as in Fig. 48, or, as in the case of the small drains, circular or tubular.

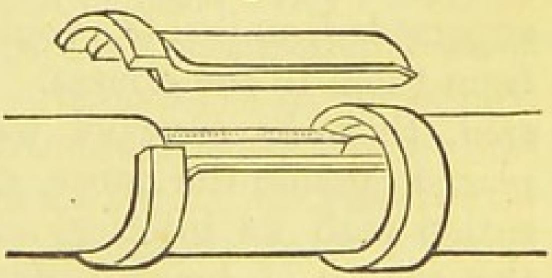
In laying drains, certain points of importance should be carefully attended to. Throughout their length, the drains should have a considerable fall or inclination. Indeed, it is not easy to give too great a fall to drains. In changing the direction of the drains, all angular bends should be avoided, as at these points the drains are apt to become choked with the solid matter accumulating there, and easy curves substituted. Where one drain tube joins another, conveying fluid to principal drain from a side source, the junction should be effected by a "circular junction," never at right angles. As we have pointed out, all sewage drains must be impermeable, so as not to allow of the liquid sent through to gain access to the surrounding soil. Great care should be taken to have the joints at the various lengths of tubes efficiently made. A jointing of well-worked clay is found to be as efficient as any other material. If the joints are not "made good," the liquid portion of the sewage will not only pass through to the soil, thus rendering it unhealthy, but the solid portion in the interior of the drain will be retained, and thus tend speedily to choke it up. The "bedding" of the drains is also of importance, so as to enable the same level to be retained at which they are originally laid. To effect this, it is a good plan to place each length of tube in a bed of well-puddled clay. Every precaution should be taken to see that the workmen employed do not leave the work in a badly made or unfinished state. All underground work is apt to be carelessly and badly done, for the defects, however serious, are buried with the materials, and not easily inspected. The efficiency of one drain, or set of drains, may be considered a small matter; nevertheless, it is those failures which create so much disease amongst us. The laying down and the repairing of drains is very much facilitated by the new forms and plans of laying tubes. One great difficulty found to be attendant upon the system of laying the drain tubes with sockets, originally used, was the impossibility of examining the condition of their interior, or in the event of obstructions preventing the onward flow of the sewage, without disturbing or taking up the whole length. Nor was the difficulty a small one when a length on examination was found to be broken, thus destroying the continuity of the system; replacing it necessitating the taking up of one or two adjoining lengths. This last difficulty has been overcome by using the system of "saddle-jointed tubes." In this, a saddle or concave "chair" is laid at the joint where two tubes meet, the end of each length being placed into and resting upon a socket or shoulder, the whole being covered with a moveable cap or cover; by simply moving two of the caps, the tube resting on the saddle or chair below can be lifted up and replaced by a new length with great ease. In Fig. 49, we illustrate "Creek's Patent Capped Drain

Fig. 49.



Pipes," another contrivance by which the interior condition of the system of drains can be easily ascertained, and obstructions removed. Where side junctions are required to be made, these can be done very easily by the cap-junctions, as shown. These capped pipes are made by Messrs Standing & Martin, Bourne Valley Wharf, Nine Elms, London. In Fig. 50, the "Opercular Drain Tubes," as made by Mr H. Doulton, Lambeth, London, are illustrated; they are used for the same purpose as the last, but admit of the pipes being examined at any part of their length. Mr Jennings, Palace Wharf, Stangate, Lambeth, London, so well known for his many sanitary contrivances, has introduced a "telescopic drain-pipe connection," for the purpose of obviating the necessity for cutting drain pipes to any required length, to fill up spaces or broken parts. By the use of the "connector" any broken

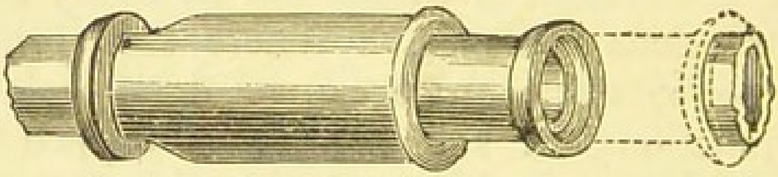
Fig. 50.



length, from two inches to two feet, can be made good without cutting the pipes. This contrivance is illustrated in Fig. 51.

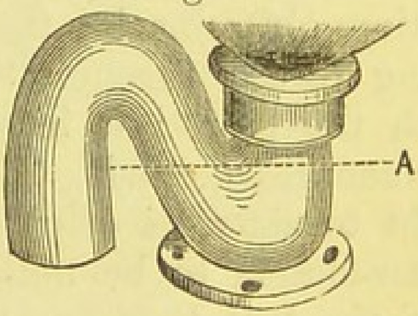
As already stated, the tubular drains are connected with the water-closets, sinks, and baths in the interior of houses, and the drains with the main sewers, it is therefore obvious that unless special means be taken, the foul gases generated in the interior of the drains and sewers will pass up from them and be led into the houses by the openings at the connections of the above. In one sense, and in many cases a true one, drains and sewers are but "elongated cesspools," as indeed they have been called, and creating, as they must create, a vast amount of foul air in the aggregate, they

Fig. 51.



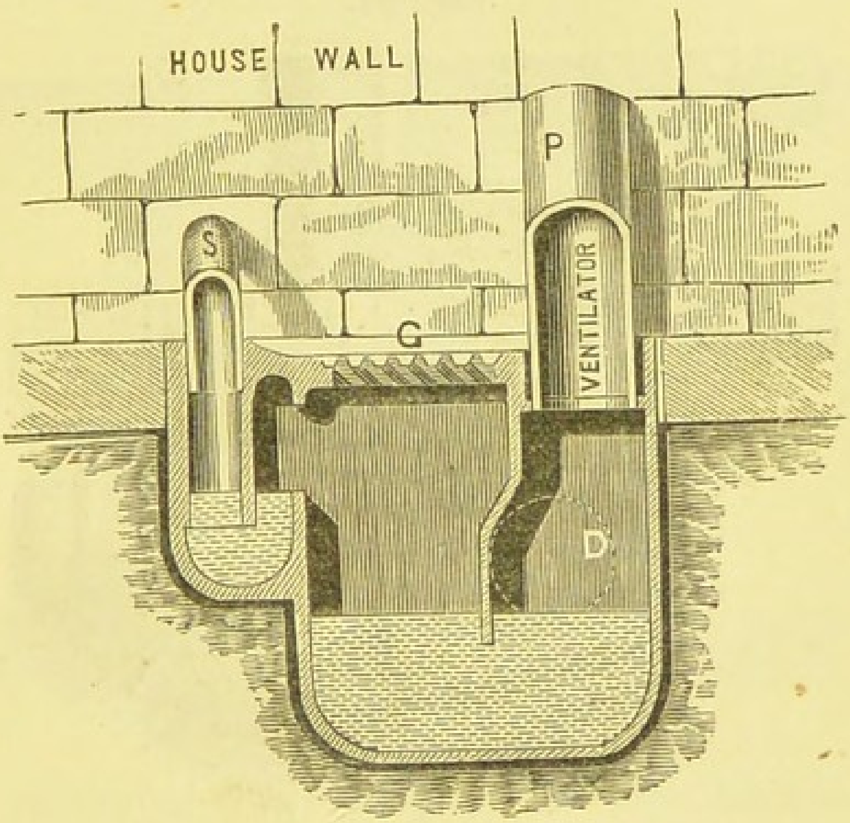
are certain to act in a way as dangerous, if not more so, as the old cesspools, which they have in large measure superseded, unless the foul air is prevented from passing from them to the houses. In one way, it may indeed be said, that the cesspool was not so dangerous, as being placed outside the house, and having no direct communication with its interior, any foul exhalation from it had the chance of being diffused in the air, or blown away from the neighbourhood of the house by favourable winds. Whereas, the drains and sewers of the modern system are placed in direct communication with the interior of the house, so that if the foul gases escape from them at all, they are delivered to the parts where they are most dangerous, and must perforce pass through the house before they escape—if they can escape—to the external atmosphere. Hence arose the absolute necessity for introducing some means of preventing the gases created in the drains and sewers from passing into the interiors of the houses with which they are directly connected. This was effected by the use of what are called, graphically enough, "stench traps," which were fixed inlets and outlets of the drains. A "stench trap," or, in other words, a "water seal," is a contrivance in which the exit aperture, or that leading to the drain, is always at such a level that a portion of the liquid passed down the trap, as from the kitchen or scullery, a sink, or bath, or the water-closet, remains to cover that part round which the foul air from the drain attempts to pass into the house, or through the upper opening of the trap, this being done by forming a syphon bend as in Fig. 52. By this arrangement the poisonous gases from the interior of the drain are supposed to be prevented from passing through the trap, so long as it is completely filled with water.

Fig. 52.



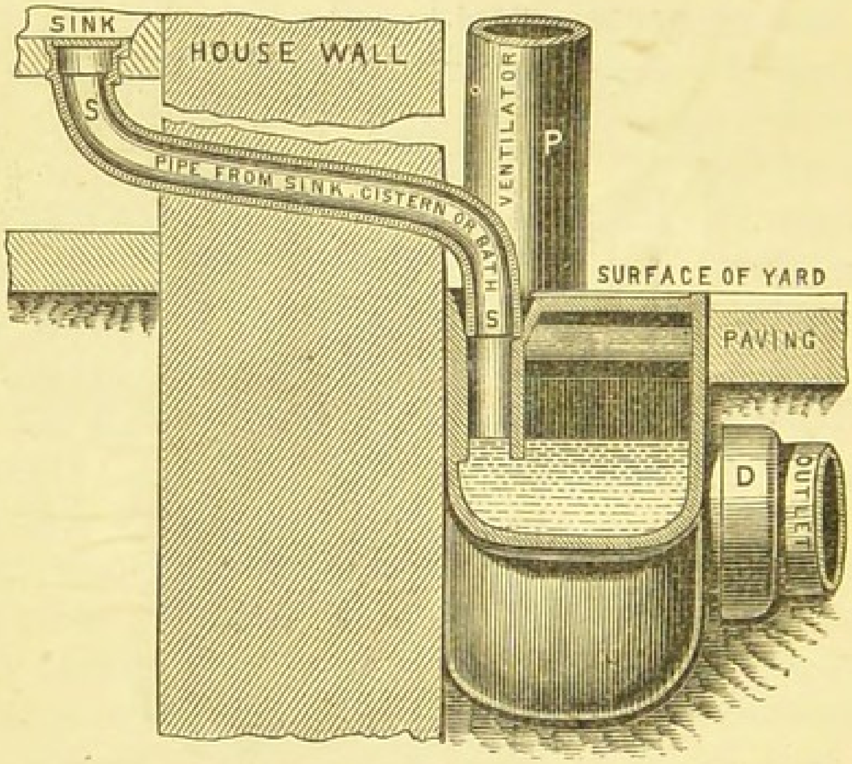
We say above, that in the use of the "trap" the gases are "supposed" to be prevented from passing from the drains to the house, and this is literally true, for in many cases it is a mere supposition, the fact being that in many cases the "trap" does not act as such. Its efficiency, at all events, is very doubtful in the generality of cases; for the body of water in the trap or the weight of the "water-seal" may be altogether incapable of resisting the pressure of the gases acting from the drain side of the trap, in which case the gases are simply forced through the trap and pass at once into the house. In addition, moreover, to the ease with which under certain circumstances the gases from the drains and sewers are forced through the small column of water in the trap, below the line *a* in Fig. 52, this in certain forms is frequently evaporated, leaving the trap dry, and of course in this condition it is only a trap in name. This happens most frequently with the "bell trap," which unfortunately is very largely used for sinks, yards, etc., etc. Experience has now shown—if scientific deduction had for too long not been attended to—that traps are in a great many instances inoperative. A very simple proof is open to the inspection of many. Drainage gases are known to contain, as one constituent, sulphuretted hydrogen gas; this discolours white lead exposed to its action. White lead is used in house paint. If the under side of the cover or lid of the water-closet, for example, be painted, and this be closed, the paint becomes in course of time quite black; this is caused by the drainage gases being forced through the trap and coming in contact with the paint; if it were not so, the paint would not become discoloured. This discolouration, however, it is right to state, is often partially caused by a defect in water-closets to be noticed in a succeeding paragraph. But the fact that gases from drains are forced through the traps and into the interior of houses, is unfortunately now a matter of notoriety, and is universally admitted, hence has arisen the discussion upon the "ventilation of drains," as well as the introduction of a more efficient form of trap. In Figs. 53 and 54 is illustrated a form of trap invented by Mr Mansergh, and manufactured by Mr Jennings, whose address we have already given. This has been specially designed to relieve house drains, and all sink, closet, and other traps, from the varying pressures to which they are subject, and at the same time to *combine in one piece of imperishable material a good sink, yard, and house drain trap*, adapted to any situation and for all drainage purposes. Figs. 53 and 54 are sectional elevations of the trap, showing it fixed as stated in a yard or area "next the house wall;" the waste pipe *s* of the sink, bath, or cistern, as also the rain or other ventilating pipe *p*, entering the trap from the top; the grating *g* receiving the surface water from the yard or area. It will be seen that the waste pipe *s* of sink, bath, or cistern, is trapped independently of the yard or surface trap, and that the rain or ventilating pipe *p* relieves the

Fig. 53.



house drain *d*, and all the traps that may be in connection with the same, *from all pressure*, carrying the poisonous gases up to or above the roof level, care being taken that the point of discharge *is removed from any attic or other window*. In the event of the sink or yard traps losing their hydraulic seal by evaporation or other causes, the upcast draught due to the rain or ventilating pipe *p*, and the open yard or area grating, prevent the possibility of sewer gases entering the house by the sink or other pipe *s*. In cases where the rain water pipe cannot be made available as a ventilating pipe, owing to the upper part of the pipe being near a bedroom window, the rain water may be discharged on the surface grating *g*, and a length of inch gas pipe may be fixed to act as the ventilating pipe of the house drain, the point of discharge, as before stated, *being removed from any window.* The sockets on the top or side of these traps, intended to receive the rain water, are

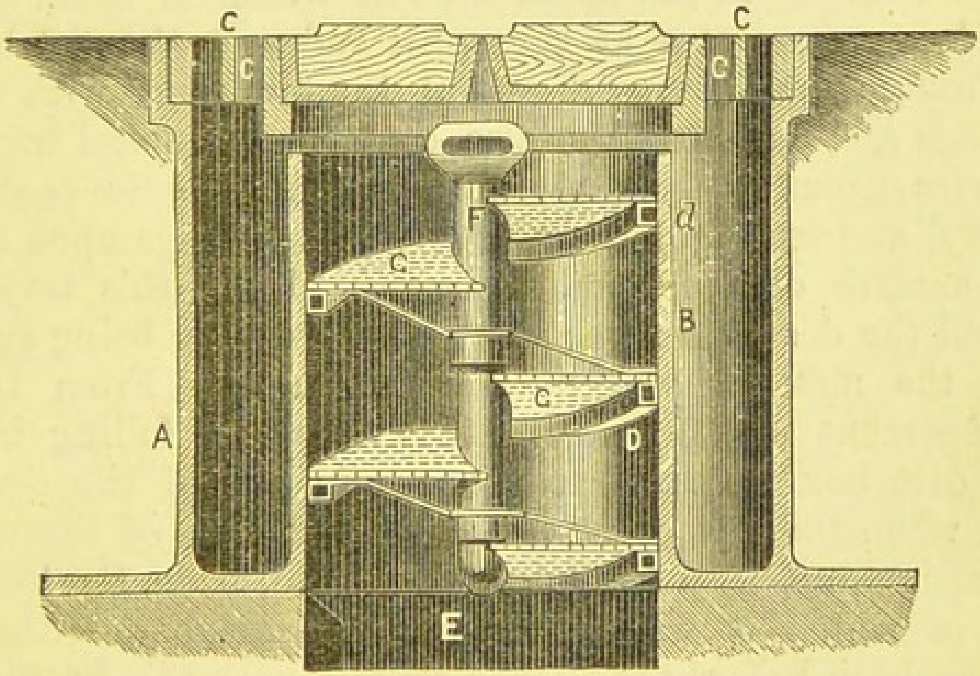
Fig. 54.



equal to the reception of a 4-inch iron rain pipe, and those for the sink waste equal to a 3-inch. As by this arrangement no trap is required in the sink, the discharge of waste water is direct from the sink to the trap *outside the house.* By the removal of the grating *g*, any deposit within the trap may be removed without trouble.

Dr Stenhouse, some years ago, showed the value of charcoal as a disinfector in cases where sewage gases were passing from drains and sewers to the open air. The result of his investigations and experiments was the introduction of sewer ventilators, in which the gases were forced to pass through and in contact with layers of charcoal. Many of these have been applied, and with admirable effect, to the gully traps in streets, by which communication is made from the surface street drains and the interior of the sewers. These gully traps or openings, as a rule, act very much as mere introducers of the foul gases of the atmosphere to the upper air, contaminating

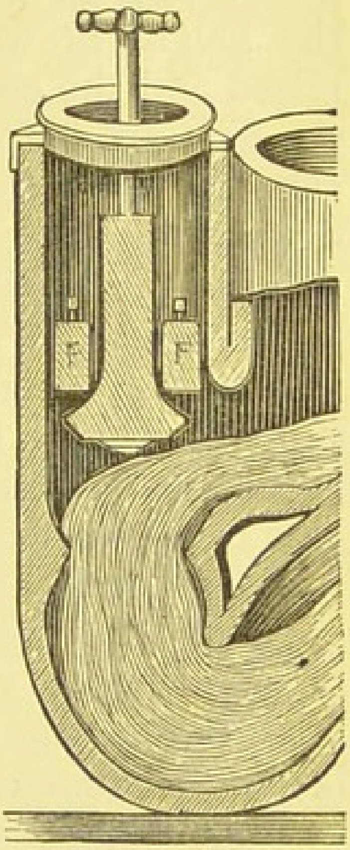
Fig. 55.



it, and rendering it unhealthy. The case is all the worse where the gully openings are in close contiguity, as they often are, to house windows and doors. In Fig. 55, we illustrate a form of ventilating and disinfecting traps for sewers, the invention of Mr Baldwin Latham, the engineer, who is now so well-known in connection with sanitary engineering. This, as described in *Engineering*, to which we are indebted for the illustration, "consists of a series of spiral channels arranged round the inside of the ventilating chamber, and containing a deodorising material. These channels are so disposed, that while they admit of any water running down freely, no impure gases can pass upwards without coming in contact with the odorising agent. This is effected in the manner shown in the drawings, of which Fig. 55 is a longitudinal section; from these it will be seen that *a* is an iron annular dirt box, enclosing a central chamber *b*, communicating at the lower end with the passage *e*, leading to the sewer, while at the upper end it communicates through the apertures *c*, in the cover *c*, with the atmosphere. To the sides of this chamber *b*, is fixed the spiral channel *d*, the upper side of which is open, and which communicates at the upper end with the dirt box *a*, through the opening *d*, and at the lower end with the passage *e*. The chamber also contains the spiral tray *g* of wire gauze or perforated metal fixed to the central stem *f*, and resting loosely with its outer edge upon the top surface of the spiral trough *d*. Upon this tray is placed the deodoriser, the angle of the surface being such that the material will not slip down it. From this arrangement it will be seen that the water falling into the dirt box *a*, through the openings *c* of the cover will, when the dirt box has become full, flow off through the aperture *d*, into the spiral channel *d*, from the lower end of which it will fall into the passage *e*, without having been brought at all into contact with the deodorising material, while any noxious gases entering the lower end of the channel *d* from the passage *e*, will, in passing up through the channel, escape through the perforations of the tray *g*, in among the deodorising material. On the other hand, all the gases entering over the lower end of the spiral tray will, in travelling upwards, be brought intimately into contact with the surface of the odorising material before issuing into the atmosphere through the apertures *c c*."

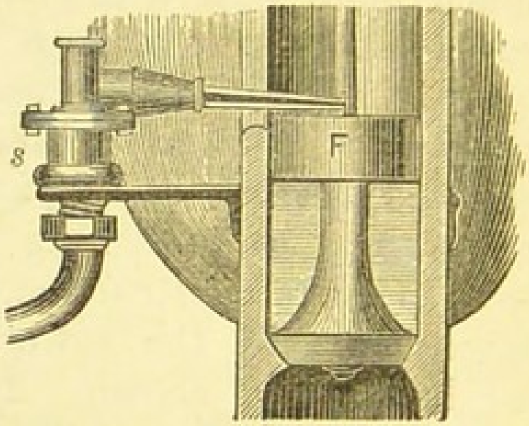
But in addition to the inlets afforded for gases to pass from the interior of the drains and sewers to that of the houses to which they are connected, through failure of the traps to act properly, other inlets are afforded by the failure of the pipes by which the refuse is led from the house, sinks, and closets to the drains. These pipes are, in the majority of instances, made of lead, and the action of the sewer gases upon this substance is such, that in a comparatively short space of time it is corroded, and the pipes break out into small holes. Through these the sewer gases find easy access to the interior of the house. This evil is not known to many, it has not, indeed, till recently been discovered to exist, but it is one much more widely existant than is supposed. It is perhaps more frequently met with in the case of water-closets, which, as generally constructed, are too easily put into bad repair, and as presenting too much lead in their construction, which is acted upon by the sewer gases, as we have above shown. By far the best material for water-closets is glazed earthenware; but the difficulty in making them, so as to have the valves and the whole throughout made entirely of this material, has been such that it is only recently that a form has been introduced. This is partly illustrated in Figs. 56 and 57. The whole apparatus, pan or basin, trap, and valve, is of earthenware throughout. It is manufactured by Mr Jennings. It is entirely free from all machinery. "No wires, cranks, levers, regulators, or other complications, to get out of order,—*the basin, the valve-seat, and trap*, being complete, and that in *one piece of imperishable*

Fig. 56.



material. In action, this closet will be found quite *noiseless;* in construction, *most simple;* in use, *efficient.* In the different qualities of ware, it is adapted for every class of building. It only requires to be cemented air-tight to the soil pipe or drain, and the water laid on from cistern or main. The above illustrations, and following description will enable any one to understand the principle and details of this closet. Fig. 56 is a view partly in section, the water being kept in the basin by the hollow plug or waste pipe, which at all times regulates the height of water. Fig. 56 shows the hollow plug raised and the contents passing away,—at the same time the float *f f*, losing the water support, opens the valve, and ensures an immediate wash, as also the required *supply to the basin.* Fig. 57 is a view of the arrangement for supply, nothing more being needed than a common service pipe from the cistern or main to the union joint *s*."

Fig. 57.



One great defect in a form of water-closet very largely used, is the large surface of the iron pan which is placed below the stoneware basin; and the surface of which pan is very rapidly covered with a decomposing material which, being open to the atmosphere, gives off much foul air. In some forms of water-closet pans there is no less a surface of this kind exposed than four and three-quarter feet. Another defect is the ease with which the swing-valve gets out of order, allowing leakage, and, in consequence, the passage of the foul air from the drain to the house. The form of pan and valve in the preceding illustration is, we think, one calculated to get rid efficiently of the defects here named.

But in view of the fact that in a very large number of cases water-closets and their "traps" are defective, and allow readily the escape of the gases from the drains into the houses—gases which are now universally acknowledged to be a prolific cause of "enteric fever"—it is now a practice in many houses to disinfect the water-closets and pipes in immediate contact therewith, by pouring down from the seat of the closet certain disinfecting fluids, as chloralum, carbolic acid, etc., etc. This, as generally done in a rough and ready fashion, is, of course, so expensive, involving, as it does, the use of a large quantity of the disinfecting fluid, that it is only available in the houses of the wealthy. A method of using a disinfecting fluid in an economical, yet thoroughly efficient way, has, therefore, up till now been a desideratum; and this, we think, is produced by the simple yet ingenious apparatus, the invention of Dr M. A. Gardiner Brown, surgeon, introduced to public notice by the "Chloralum Company, London," who have purchased the patent. The apparatus consists of a reservoir containing chloralum, and communicating by means of a small tube with the down-flow or water pipe from the cistern to the closet-pan in such a way that the water flowing through this supply pipe draws over by suction a small quantity of the chloralum, with which it becomes thoroughly commingled. The right amount of the disinfectant to be used is determined by a measuring tube within the apparatus; which also prevents any one wasting the chloralum, whilst at the same time there is a full and sufficient quantity discharged for the purpose of neutralising all effluvia from the closet. The disinfector is easily fixed, and cannot get out of order; and should in public places be enclosed in a wooden box constructed for the purpose, with a lid at the top, so as to admit of charging it from time to time. Its capacity is one gallon, other sizes being made to order; its general form that of a cylinder twelve inches high by six inches wide. It stands on a bracket in that corner of the closet which contains the water-pipes. It acts upon all occasions when the handle of the closet is pulled. A float-staff passes through the lid in order to indicate, by its falling, when it requires re-charging.

The apparatus is charged by turning the handle, through which the float-staff passes, and pouring in one pint of chloralum, and then filling up with water. The length of time that each charge lasts will, of course, vary with the amount of use the closet is subjected to; in a household of eight persons it would last about five or six weeks. The gallon size will allow of about 250 ordinary pulls at the closet handle before it is empty, and is only calculated for family use.

But as prevention is always better than cure, and however efficient may be the means adopted by which the foul gases generated in, and always present within our drains and sewers, may be prevented from passing into our houses, or disinfected before they gain access thereto, and in view of the fact that an enormous proportion of the defective appliances at present in use, will remain so, and not have efficient ones substituted for them, it is imperatively necessary that all means should be taken to *carry off from the drains and sewers the gases as they are formed*, so that they be not allowed to accumulate there till they become very dangerous. This, as far as present experience goes, seems most likely to be effected by the use of special ventilating shafts, into which the gases are led or drawn by the aid of fire draught, and delivered at a zone considerably above that of the houses. Failing the adoption of these specially designed ventilating shafts, it is proposed to avail of the large number of factory chimneys met with in many towns, and which afford great facilities for withdrawing gases from drains and sewers, and delivering them into the air at such an altitude as will insure them being diffused through the atmosphere, so that they will not descend to pollute the air supplied to our houses. Liverpool has taken the lead in the adoption of special ventilating flues for this important purpose, a very large number having been erected in that city. (*See* a succeeding paragraph descriptive of the system of treating the excreta of the population in that town.)

But as we fear that it will be a long time before our town corporations generally, follow the spirited example of the corporation of "lordly Liverpool;" and as therefore the system, so generally accepted, of house drains and sewers, with its train of defective traps, will remain to act to a large extent as contaminators of the air in the neighbourhood of houses, and, what is worse, of that supplied to their interior; it is of great importance that a system of drain and sewer trapping, thoroughly efficient in all respects, should be adopted, and that without delay. The question is, however, what should be done in this direction? This may be answered, as we think it has been pretty fully and conclusively answered by Mr Lovegrove, C.E., who has given much attention to this department of sanitary construction, in a paper read recently by him before the Society of Arts. Another plan recently proposed, to get rid of the evils arising from the formation of drain and sewer gases, is that of Mr Macpherson, the Sanitary Engineer of Edinburgh, who proposes to place charcoal disinfecting traps or boxes *within* the sewers, so as thus to act immediately upon the gases as they are formed.

What has now been given on the subject of emanations from drains, and on the methods proposed by which they are either to be prevented or rendered as innocent in their action as possible, will show, however, that under present circumstances, and which we fear will be those of a large proportion of our towns for years to come, it is necessary that special attention should be had not only to the construction of water-closet appliances, but to the ventilation of the rooms or places in which these appliances are placed, more especially if these are within—as they in nine cases out of ten in the majority of our towns are within—the interior of the house. As a rule, the rooms or *closets*, in which the seats and apparatus are placed, are too small. They should be of dimensions superior to that of a mere closet; they should also be well lighted, which they not often are; and they should be well ventilated, which they very seldom are. In the flat system of house building, the *closets* are generally seen in their worst state, of miserably small and cramped dimensions, almost always totally dark. They are rendered still greater nuisances by not being ventilated to anything like a proper degree of efficiency. Placed generally not far from a chimney, it would be no difficult matter to arrange a flue in connection with this, by which the withdrawal of the foul air would be a matter of certainty; and being, as a rule, situated close to the staircase, means of obtaining a supply of fresh air are within reach, or a special flue might be made leading from the external air for this purpose. In many cases, the only means of ventilating—so called—applied to closets in houses on the flat system, is a small window or opening communicating with the general staircase. If this does act as a ventilator, it only acts as a shifting of the evil, supplying foul air to the staircase, which in turn gives a supply to the houses. If the staircase were properly ventilated, the evil would be less marked; but staircases, as a rule, are not ventilated, as, indeed, may be known any day by the sense of smell on entering them. And yet, lighted as they generally are either wholly or partially by sky-lights, a ready means of securing efficient ventilation is offered, if it would only by house proprietors and builders be accepted by them; and no great amount of inventive or constructive ingenuity is called for in accepting the opportunity, and making the ventilation of a common staircase thoroughly efficient. In detached suburban and rural houses, the difficulties in the way of giving roomy, well lighted, and efficiently ventilated water-closets or rooms, do not exist as in the case of town houses, and no excuse should be accepted of the builder who does not give all these advantages.

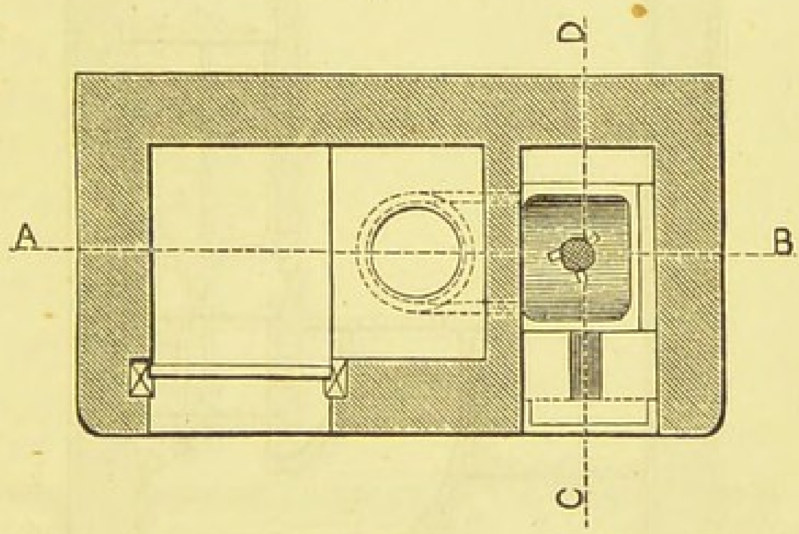
As the presence of the sewage matters in the long continuity of our town drains and sewers is that which of course gives rise to the gases, it is of great importance that these should be carried off as rapidly as possible to the place of final deposit, and not be allowed to remain in a condition more or less stagnant in their interior. This will be secured by giving, in the first place, as great a fall as may be attainable by local circumstances to the drains and sewers throughout their whole length, so as to secure the highest degree of velocity to their on-flowing contents; and in the second, by copious discharges of water into their interior, so as to aid the discharge and the cleaning out of the sewage. This last process, which is known as "flushing," is now greatly advocated; and many corporations, impressed with a sense of its value, are urging on the supplies of water on a greatly increased scale mainly with this object in view. But efficient as "flushing" may be for the purpose of cleaning out the drains and sewers from solid decomposing matter, we shall see as we proceed that this unfortunately only increases the difficulties attendant upon the final utilisation or disposal of what is now known as "town sewage."

Before dismissing the subject of the water-closet system, it will be useful here to describe the mode adopted in Liverpool to get rid of the old system of privies, and open middens, and cesspools.

In Liverpool, the "water-closet system" is carried extensively out. Up to 1854, at the date of the passing of a Sanitary Amendment Act, the "midden system" prevailed; but under the powers of the Act, and after due consideration of the local features of the town, and the conditions which would come up to the requirements of the medical officer of the Board of Health, it was determined to adopt the "water-closet system," but with special structural arrangements presently to be described. The decision to adopt this system arose not from a notion that it was the best way to dispose of, or rather to treat the sewage of a town in the first instance, but chiefly because the immediate neighbourhood of the tidal river —the Mersey—enabled the sewage to be discharged into it, without any fear of evil arising from its dangerous pollution, inasmuch as the tidal currents being very strong, and the river water not being used for domestic purposes, the sewage is swept away to sea so speedily and completely, that no deposit in the river is the result; and also from the fact that the water-closet system admitted of the sewage being carried away in the quickest way from the houses. The almost universally used middens and open privies are fast disappearing, no new ones being allowed to be erected; and those still in existence are being rapidly converted into the trough water-closets, now to be illustrated and described. Under this system an ample supply of water is requisite; and this is provided entirely by the corporation, at the rate of twenty-five gallons per head. The private wells are now nearly altogether enclosed and disused, the water from them having been found very much contaminated with sewage matter. In Fig. 58 we give a plan; in Fig. 59 a section on the line *a b* in plan; and in Fig. 60 a section on the line *c d* in plan of the "trough water-closet" adopted in Liverpool. In Fig. 60, *A* is the water supply from the hydrant, with the hose inside the chambers.

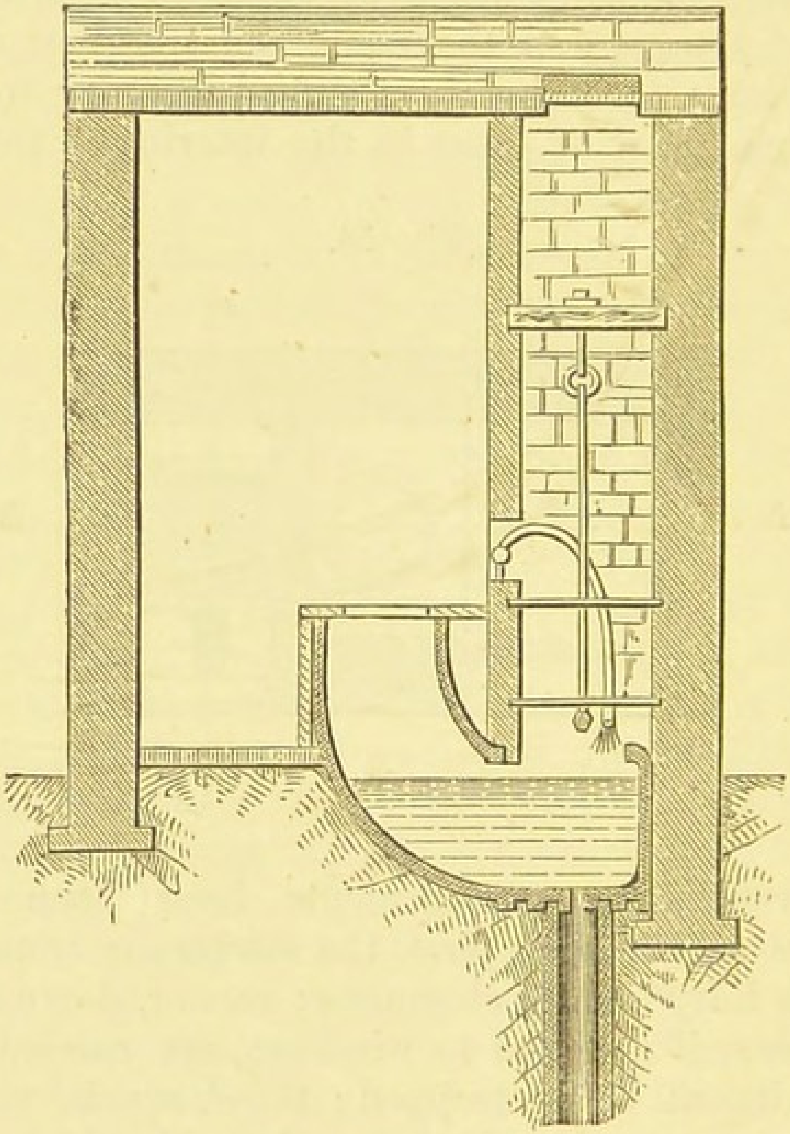
The parties using the water-closets have no power to turn on the water themselves, the tap being kept under lock and key by the authorities. The contents of the closet are once a day well flushed into the sewers, while at the same time the courts and alleys are well washed by the water supplied by the hose from the hydrant, by officers appointed by the corporation for this duty. Special arrangements are thus made to flush the whole system of sewers, and to ensure the speediest discharge of the sewage into the river. And in order to prevent the accumulation of gases in the interior of the sewers,

Fig. 58.



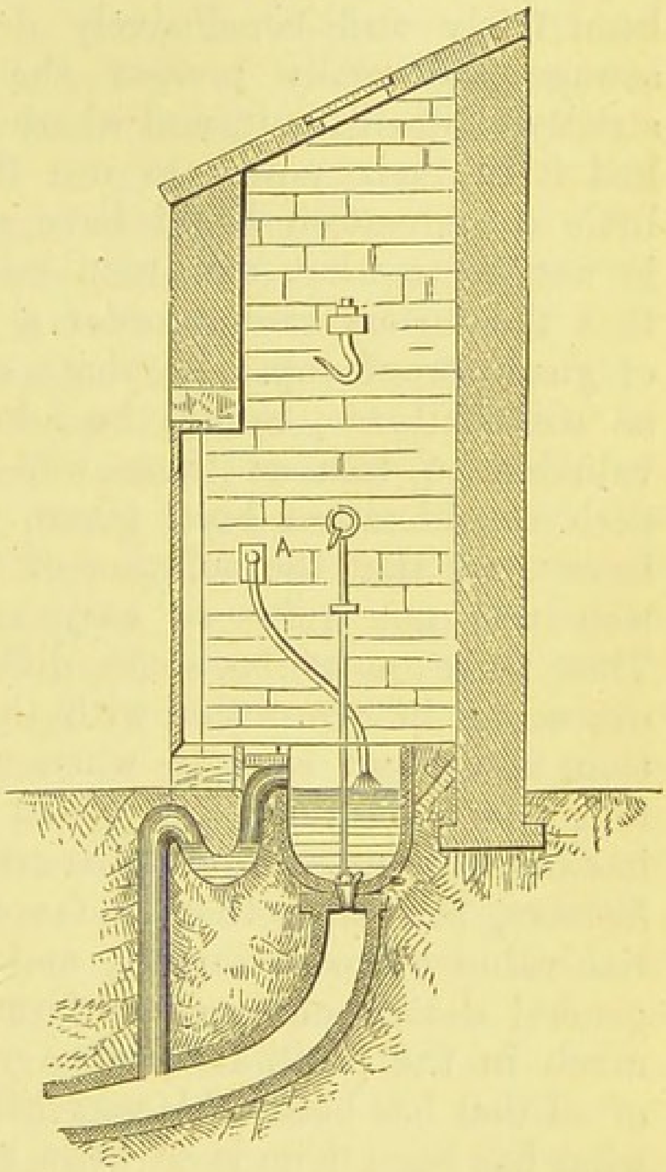
special ventilating arrangements have been adopted. These are as follows: *first*, the sewers are connected by flues with lofty factory chimneys; *second*, down spouts of high houses, if not near to windows, are carried into the sewers without being trapped; *third*, special ventilating chimneys are employed, the outlets of which are provided with the Archimedian Screw Ventilators, which we have illustrated in Fig. 42, Chapter III. The sewage, amounting to an ordinary average flow in dry weather to twenty-five millions of gallons per day, is discharged into the River Mersey at eight different points. A concession has recently been granted by the corporation to a company, who pump so much of the sewage by steam power on to a farm of 60 acres, which lies somewhere about eight miles from the town. The experiment, so far, has not been, we understand, successful.

Fig. 59.



We now come to the consideration of the important subject—*the ultimate disposal of the town sewage.* From what has been said, the reader will perceive that one result of the new system of town drainage and sewerage has been the creation of a vast supply of "sewage" largely diluted with water, and greatly contaminated by the presence of the excreta of our population. Shortly after the water system was first carried out on the large scale, the difficulty of dealing with the large volumes of sewage, which was the result of it, presented itself—a difficulty which increased with every increased application of the system. In view of the fact that the sewage possessed a value more or less decided as a *manurial agent*, it was very early proposed to get rid of the difficulty by using it for the irrigation of land. But obvious as was this application, its practical realisation was not found to be so easy as it was at first thought, and is yet popularly supposed to be. One result of this was, that the blame—if blame there was, attachable to any one in connection with a subject which is characterised by so many difficulties as the disposal of town sewage is—was laid to the credit of what was, and is still, popularly called the "stupidity" of the farmers in going to great ex-

Fig. 60.



pense in procuring manurial substances, from great distances, when such a valuable one was lying, so to say, at their own doors, and obtainable at an easy purchase rate. Much of this reproach might have been spared had the public taken the pains to ascertain in a plain matter-of-fact business-like way, whether it had been fairly and conclusively decided, that this town sewage did really possess the agricultural value so strictly claimed for it, and whether the farmers have ever had it in their power to use it practically. A very little consideration would have shown that this sewage is not quite what one may call a "portable" article, that the farmer cannot order a *ton* of it, as he would of guano or of superphosphate, even admitting—which, as we shall see, cannot be admitted—that it was as valuable to him as these well-known manures. Had such consideration been given, the public would soon have seen that the solution of the town sewage question was not quite so easy as has been supposed. That there must be some difficulties not easy to be overcome, in connection with the solution of the question, is evident enough, when we consider that a very long course of years has passed away since the subject has been discussed, and apparently settled as against the farmers, and altogether in favour of the high manurial value of town sewage, and its applicability to the general details of practical farming. Yet we are very much in the position we were years ago; and, in spite of all that has been said, very little has been done. And what has been done is so little satisfactory, that we find one of the largest and wealthiest Towns of the Kingdom, after spending a large amount of time and money in investigating the whole subject, coming to a decision nearly the very opposite of that which Boards of Health and Government Officials, and a large and influential body, moreover, of Scientific Men, have done their best to induce the public to believe was the only and right decision to come to. And we find the Corporation of this town (Birmingham) about to inaugurate a system of treatment and ultimate disposal of their town sewage very closely approximating to what we have for long advocated as the one most likely to be generally available for towns situated as Birmingham is.

While, doubtless, it is true, as we have elsewhere remarked, that the mobile vehicle of water is one admirably adapted to aid in the removal of the sedimentary matter usually contained in sewage water, and that the more water you can send down your drains and sewers, the less chance will there be of their becoming choked up with deposits; still, on the other hand, it is equally true that every addition to the moving or flowing force of the sewage matter, obtained by increasing the quantity of water, must of necessity decrease the value of the sewage as a fertiliser. Thus, while we perceive that if the object of our town drainage system is merely to convey away the sewage as quickly as possible, the admission of water to act as the moving power is essentially necessary, if efficient drainage be desiderated. It is also obvious, that if the object of our town drainage system be to supply us with a fertiliser, in addition to its other objects, the more water we add to our drains the further do we depreciate the value of the fertiliser. Thus, then, we find, that if we advocate the tubular system of drains with their water carriage as the correct one, we are placed in a dilemma out of which it is difficult to move. If, to keep the sewage matter as strong as possible as a fertiliser, we do not use much water, then, by the stoppage of the drains, or at least the sluggish flow of the sewage through them, we do not come up to the sanitary requirements of the question; we make our drains, in fact, "elongated cesspools." On the other hand, if we sweep out quickly the contents of our drains by the aid of large bodies of water, we reduce the value of the sewage as a fertiliser, and do not come up to the agricultural requirements of the question; adding also to the difficulties attendant upon using the enormously large bodies of fluid thus produced.

The whole question is manifestly one of the greatest difficulty, but we have always maintained, and that for a long time, that it is one which concerns the towns chiefly, not the country districts. The duty of all corporations is to get rid of the nuisance which sewage is, if left to remain in and near the neighbourhood of houses; and this riddance is, if there is anything in sanitary science, an imperative duty, to be performed at whatever cost. If, in the getting rid of the nuisance, from a sanitary point of view, they can make anything of it, from an agricultural point of view, good and well, let them do it, and then "rest and be thankful." But if they go in to make money the almost primary consideration, they must, in taking this commercial view of it, do as other commercial men do, take the sewage to the market. When they do take it, we fear that, in some instances at least, they will find the market will not be so very good. Only of this let them rest assured, that the farmers are not the foolish fellows some say they are, and that if, when it is put before them in such a way that they can use it, they will do so, if it be worth using. Under the present aspect of the question, it is quite obvious that much has to be done before they can put it thus to the test in a general way. Mahomet, in this case, cannot go to the mountain, the mountain must go or be taken to Mahomet. And this taking of the mountain is the work of parties other than the farmers—we say it is that of corporations.

In connection with the supply of manure to our agricultural districts, it might be taken as a maxim, that the more concentrated it is, the cheaper it will be to the farmer. On this point Professor Way remarks: "The carriage of a cheap manure was obviously the same as that of a dear manure. Guano, for which they were paying ten pounds a ton, they could take into the country at a cost of not more than ten per cent. of its value; but this same cost of carriage would amount to 100 per cent. on the value of a manure costing one pound per ton, and the farmer could not afford that. The tendency was very properly now to increase the value in a given quantity of manure. If it was worth thirty pounds per ton, so much the better, provided it contained the same value as could be supplied by thirty pounds worth of other descriptions of manure." As all are agreed in the one point, that sewage matter of towns, even when largely diluted with water, is a fertiliser of some value, the point narrows itself to an engineering one, whether it can be conveyed to the land at a cost which will render it pecuniarily valuable to the farmer. It is upon this the whole question hinges, and it is on this that opinions become so opposed to each other, that it is very difficult to decide which is right. If the present system of tubular house drains, leading to sewers, and these again to streams and rivers, is to be carried out, then it is clear that on the one hand we commit a great waste in an agricultural point of view, by throwing needlessly away that which, beyond all doubt, contains a comparatively large quantity of fertilising materials useful for certain crops; and on the other, we commit a great wrong in a social and sanitary point of view, by polluting our streams and rivers, poisoning the very sources from which we obtain the water useful for household purposes, or making our rivers huge open cesspools, to flow past or through our towns, sending forth from day to day "the seeds of disease and death." But even supposing that the in every way absurd method of conveying our town sewage to river outfalls is discontinued, and plans adopted by which the liquid sewage is arrested in its progress, prevented from entering the river and stored up, and dealt with either by pumping it directly on to the land, or treated so as to make it part with its fertilising matter in a solid form, still the present system of drains, necessitating, as it does, the use of water to make them efficient, presents difficulties which seem inherent in the system; for it is evident the more the population becomes extended, and the farther the present principle—the conveying through the drains "*all* the refuse which can be estimated to float in water"—is carried out, the greater the quantity of water required, and the greater the decrease in value of the sewage liquid obtained. In view of these points, the attention of our first men of science has been directed to the carrying out of some plan by which both the agricultural and sanitary requirements of the question can be met. That some modification of the present system is desiderated, few are disposed to deny. Some—and the number is fast increasing—go further, and affirm that the present water system is in principle wrong; that no modification of the practice founded on it will meet the difficulty; that we shall have to begin again—inaugurate another system—at least so far as the fæcal results of our population is concerned.

It will be necessary, therefore, at this point in the consideration of the question, to state as briefly as may be the difficulties which stand in the way of a system of utilisation of town sewage by irrigation, on the large scale necessary to deal with the vast quantity of sewage met with in large towns.

And, first, as to the value of town sewage in its normal condition as a manurial agent in the fertilising of land. The chief source of such value as town sewage possesses, is the excreta of the population. These substances are the most precious of all manures, and the best destination for them is, undoubtedly, the land. They constitute, in reality, the only valuable portion of town sewage. All the inorganic matter is useless from a money point of view, or nearly so, and is likely to be prejudicial to the land. Instances, indeed, have been named of town sewage from manufacturing towns being poisonous to land. At all events, the matters in sewage, other than human excreta, if not positively injurious to land, "are certainly not necessary or desirable." The saline matter of excreta alone is useful, as "it closely resembles the saline matter taken from the land by the plants" under ordinary circumstances. Manufacturers' products in sewage may, "in lapse of time, if they do not by their chemical action injure the growth of plants, be forced by their mechanical action injuriously to interfere with the nature of the soil."

The quantity of solid excretal matter yielded per day by each individual of the population—taking all classes and all ages together—is estimated by one authority at 2 and by another at 2¼ oz. This contains 36-100ths of an ounce of nitrogen; and by the percentage of this constituent which it contains, the value of a manure is estimated. Urine contains the most nitrogen of the human excreta. Dr Parkin says: "Each individual passes on the average 2½ lb. (2 pints of urine daily, and 912 lb. in the course of the year). As this liquid contains 3 per cent. of nitrogen, according to Baron Liebig and other chemists, each individual would thus furnish 27·36 lb. of nitrogen in the course of the year. Now, 3 cwt. of guano is always sufficient for an acre of corn land; and as this manure contains, on the average, about 8 per cent. of nitrogen, the above quantity would give 27 lb. If applied in the same proportion, each individual would be able to fertilise an acre of corn land. The *excreta* of 28,000,000—the present population of Great Britain—

would therefore furnish sufficient manure for 28,000,000 acres."

But the solid and the liquid excreta do not form the only ingredients of town sewage in its ordinary condition, but they are mixed with a large proportion of drainage water, the surface or rain water from the streets, which tends to dilute it, and correspondingly reduces its manurial value. On the other hand, the value is somewhat increased by the soot, dung of horses, etc., which are swept off the roofs of the houses and the streets by the rain, and into the drains and sewers. Taking it however, in its normal or ordinary condition, the value of a ton of town sewage may be set down at twopence. In stating the price of Peruvian guano to be from twelve pounds to fourteen pounds per ton, we give the extremes of manurial value; and in the price of farmyard dung at from three shillings to five shillings, the medium value of our chief manurial agents. The manurial value of the excreta voided daily by one thousand of our population has been estimated to be, in their natural condition, fifty-two shillings and elevenpence; of which the liquid is put down at twenty-four shillings and eightpence, and the solid at twenty-eight shillings and threepence. On this calculation, 1000 of our population produce annually a a money value of £541, 15s. But this is the theoretical side of the question. There comes into the practical side of it, the enormous quantity of water with which the town sewage is diluted, so that in place of finding we have a value of over two pounds sterling a ton, we have not over twopence as representing that of town sewage in its *ordinary condition.* Not so much as that in fact, for the majority of authorities put it at between 1½d. and 1¾d; and some—and no mean authorities—put the value down so low as only one penny per ton. Such is the difference between the theoretical and practical value of sewage manure. Nor need we be surprised at the discrepancy between the two, when we remember that the same in kind, although not in proportion, exists between the theoretical and practical value of farm-yard dung. Some chemists value this at twenty shillings, others at about twelve shillings—none lower—per ton; and yet we find that in practice it only brings prices varying from five shillings and sixpence to seven shillings and sixpence or eight shillings per ton. The value of a thing is what it will bring; and, judged by this standard, what is the value, the manurial value, of town sewage?

This value is dependent upon circumstances more or less numerous. It not only depends upon what, as a fertilising substance it is, as compared with other fertilising substances, but upon the condition in which it is as affecting its transport. The more concentrated a manure is, it is the more valuable, not merely because the whole of it, or nearly the whole of it, goes to the plants' nourishment—no extraneous and valueless matter being mixed up with it—but because of the cost of transport from place to place. Valuable as we all admit farm-yard dung to be, there is a limit beyond which *it* would cease to be valuable at all, inasmuch as the cost of its transport would be worth more than its fertilising value. If in any manure there is a fertilising value, say ten times that of farm-yard dung, it is obvious that the same result—as a fertiliser—would be obtained by using a ton of this as by using ten tons of the dung. But the cost would be vastly different; one would have to pay the carriage of ten tons if one used the dung, in place of the carriage of one ton if one used the concentrated manure. But this mode of comparing one manure with another, is only correct so far as it goes—indeed, in another aspect the comparison is wrong, or at least likely to lead to fallacious results—but it is correct, so far as the bulk is concerned, of the two manures. We have, however, to take into consideration this important fact, that not only is the question of relative bulk to be taken into account, but we must consider whether we can use the bulky manure, as an eminent authority puts it, "when and where we require it." This authority further says, with reference to town sewage, and to the fact that the difference between its theoretical and practical value is no more to be lost sight of than the difference between the theoretical and practical value of farm-yard dung: "I cannot see why we should calculate the value of a still more bulky manure (as town sewage is), which is still less under our control than farm-yard manure, without taking into consideration the fact, that a manure is only valuable when we can do with it what we want, or valuable in a great measure only to that extent. The fact is, that the more bulky a manure is, the less manageable it is, and of less practical value it is also." Considerations such as these are eminently practical, and will always affect the sewage question; but it is not possible, under the present system of town sanitary arrangements, to lessen the bulk of the resulting sewage to a great extent, if indeed to any. This question of bulk is then one to which attention must be paid if we wish to come to a correct conclusion as to what chances there are of sewage being used agriculturally, in all cases where made, that is, in the neighbourhood of towns. That after the lapse of so many years, so few towns have managed to get rid of their sewage in this way, shows, beyond any cavil, that there are difficulties in the way of using the sewage. And the difficulty is—or rather we should say, the difficulties are—enormously increased by the local circumstances of many towns, and the character of the land there met with, judged from an agricultural point of view; and this brings us to the important point, as to the land required for the purposes of sewage utilisation.

Land cannot be obtained of sufficient extent in the neighbourhood of the towns in which the sewage is produced; and this may safely be accepted as the rule, when we consider that one acre is required for every twenty to twenty-five individuals of the population. The land, moreover, must be, to give the best results, of a certain quality; and locally, so far as its surface is concerned, arranged in a certain way before the best results of the application can be secured.

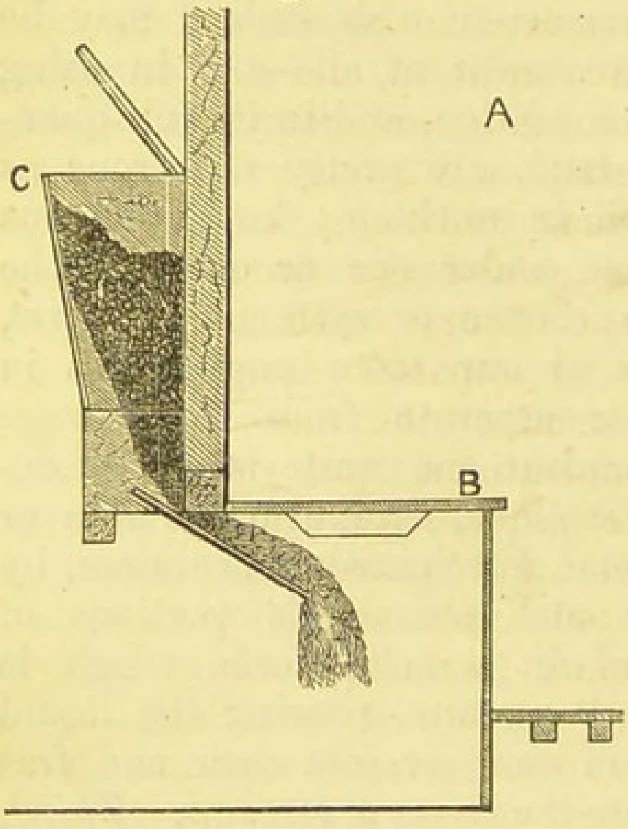
With regard to this point there is, or rather will be, if the sewage of large towns is to be used for irrigation, an almost insuperable difficulty in getting the requisite quantity, and the proper quality, of land for the utilisation of the enormous quantities produced. The Birmingham Sewage Committee, in pushing their inquiries on the subject, for example, found that the average of seven towns which have had their sewage utilised by irrigation, gave 5768 tons of sewage as the yearly quantity applied per acre; and, applying this to the case of their own town, they found that 4800 acres would be required, if the same system of cultivation or farming was adopted as in these seven towns, upon which rye grass and vegetables were the staple products grown. Now, as the committee remarked, it would be manifestly absurd that an area of this extent (nearly 5000 acres) could be devoted to such a system of farming. If they have now a difficulty in disposing of the rye grass grown upon their small sewage experimental farm at Saltby, how could they have any reasonable expectation of disposing of the enormous quantity grown upon 5000 acres? The ordinary style of farming must, therefore, be adopted, if adopted at all, and the land would require to be of double the area, or say 10,000 acres. Apart from the difficulty of getting this quantity of land in the neighbourhood of large towns, the mere cost of preparing the land—averaging this at £25 per acre—for irrigating with sewage, would be so enormous that this difficulty alone would act as a strong deterrent in such cases. Then, again, how about the management of such a monstrous farm? Are corporations to add to their own duties those arising from farming on such a gigantic scale? And, moreover, where are the tenants to come from? For, as has been well remarked, very few farmers would undertake farming if they were compelled to use all the sewage sent to them, at the risk of being indicted for creating a nuisance by their non-usage of it.

Every point, however, connected with the utilisation of town sewage by the irrigation of land, is so surrounded with difficulties, that corporations find it practically impossible to come to any right decision on any one of them. The Birmingham Corporation, for example, found, after the most extensive and searching inquiry into what had been done in sewage irrigation, and as what were the principles upon which scientific men were agreed in connection with its practical working—found that all the questions "are practically unsolved;" in place of established principles and settled opinions, they found nothing but doubt and uncertainty, and chemists and agriculturists alike holding opinions "absolutely and *irreconcilably* conflicting." On points of chemistry, of practical farming, and on financial results—this latter point being of perhaps more importance to them—the Birmingham Corporation could get no information which could lead them to definite and "certain conclusions." The difficulties of the question, moreover, are increased by finding that the experience—such as it may be—gained by one town in the disposal of their sewage, is no guide to another town, differently placed as regards circumstances of population, locality, and the like. There may be no great difficulty in dealing with the sewage of a small town; but in dealing with that of a large and densely-populated city, the circumstances are so materially different, that, as is well pointed out by Mr Hawksley, the eminent engineer, the difficulty may "become incalculably greater."

Seeing, then, the difficulties which are unmistakably attendant upon the disposal of sewage in large quantities, by adopting plans by which it is to be used in irrigating land, the question comes up, how is it to be treated, as treated it must be, if the health of the inhabitants of our towns is to be considered? The methods of treatment, or disposal, other than those involved in the systems of sending the whole of the sewage into rivers or streams—if this indeed may be considered a system of treatment at all—and in using the sewage in its normal condition, and in its full quantity in the irrigation of land, are pretty numerous as regards diversity of detail in working; but numerous as they are, they all come under one or other of the following classes. These classes or systems are, *first*, dealing with the excreta of our town populations in a special way, altogether separate from the sewage drains, leaving these to conduct the waste waters of domestic and industrial operations, and also the rain or storm waters alone. *Second*, Precipitating processes, by which the solid organic and putrescible portions of the sewage are deposited in a solid form, which is to be used as an ordinary manure, passing the liquid portion of it in a condition more or less clear and free from putrescible matter into the rivers or streams. *Third*, Keeping the rain and storm waters in drains distinct from those conveying the sewage; the rain water to be passed to the river or stream; the sewage, in a consequently more highly valuable form, as a fertiliser, to the land for irrigation purposes. *Fourth*, the filtration process, or, in other words, "the application of sewage to a moderate quantity of land, so as to make purification the first object, and cultivation the second, with the view of passing the affluent water as quickly and cheaply as possible into the river." These various systems we propose now briefly to describe, taking up these in order as above named.

Of the first of these systems, namely, that which proposes to deal with the excreta of our people, in a special way, apart altogether from the liquid refuse of houses, or the storm or rain waters ; in other words, the treatment of the solid and liquid excreta separately ; a well-known example is that of Moule's Dry Earth closet. The deodorising and absorbent power of dry soil or earth has long been known, but a systematic mode of applying it to the treatment of the excreta of our houses is due to the Rev. Mr Moule, who has introduced several mechanical arrangements by which it can be used. The general principle of these is illustrated in Fig. 61, in which *a* is the closet, *b* the seat, *c* the receptacle for holding the supply of dry earth, a contrivance being attached to it, by which, after using the closet, a portion of the soil is made to cover the excreta. However efficient as a deodoriser and absorbent of fæcal matter dry earth may be—although it may be here remarked that it

Fig. 61.



is not so efficient as it is by some maintained to be—it is obvious that there are almost insuperable difficulties attendant upon its use on the large scale, which will prevent its being adopted in towns.

There are, moreover, certain difficulties attendant upon the use of Moule's apparatus, which will retard its very general introduction even in *country* districts ; thus the quantity of dry earth required for each time the closet is used is so considerable, that it will in some cases be a matter of difficulty to get the supply of earth kept up ; and this will be increased by the fact that the earth requires to be well dried, and in a state of fine division. The mechanical arrangement of the closet is also such, that the covering of the excreta is not always secured. Nor is the value of the manure anything so high as was at one time supposed. This has been, we think, conclusively proved by the experiments recently published by Dr Voelcker in the "Journal of the Royal Agricultural Society of England," The objections which obtain to the use of Moule's apparatus are, we think, got over by Sandford's carbon closet. In this, the mechanical arrangements are so well devised, that the excreta are covered by the deodorising material with absolute precision and accuracy. The material employed is charcoal obtained from seaweed. Very little is used each time the closet is put in requisition, as compared with the dry earth in Moule's apparatus. And, while it is an excellent deodoriser, it is also in itself a manurial substance of such value, that it will pay for itself if used as a manure ; but when mixed with the excreta, the value of the manure is much increased. Where the closet is a fixture—for the system is applicable to commodes—the charcoal is drawn from a reservoir on the roof of the house, and after it is mixed with the excreta, it is discharged in a dry state into a concealed vault in the basement. The liquid refuse of the bedrooms is discharged into a small urinal placed in each floor, and conducted from this by a lead pipe to the vault in the basement, where it is mixed with the charcoal and excreta passed from the closet above. The vaults in this system are emptied at intervals—in the case of private houses once a year—and the manure taken to the establishment of the company which works the patents, and is there passed through certain processes, which result in the obtaining of valuable products, as charcoal, tar, gas, and manure.

Another system, belonging to the class now under consideration, and which is highly spoken of as applicable to public works, is that known as "Strang's Patent Sewage Filter." This consists of a cast-iron box, which is placed as near the drain or sewer as possible, and which receives the contents of the closets in the works or ranges of tenements. This box is divided into two compartments, the lower of which is deeper at one end than the other, the upper compartment being rectangular, the two compartments being separated by a perforated grating, which carries or supports a bed of common ashes. The solid and liquid excreta are passed into the lower compartment, the solid portion gravitating towards the small and outside end, and which is provided with a valve or door by which the solid part is withdrawn, and discharged into a portable covered ash-box, which is removed from time to time as filled. The liquid portion passes upwards through the bed of ashes in the upper compartment of the box, and is finally led off in a condition said to be "perfectly freed from all contaminating matter," by a pipe which communicates with the drain or sewer. This apparatus, it is obvious, can be applied to the present water-closet system, and admits of closet apparatus of a much more simple character than that now in use. The manure obtained by the use of the Patent Sewage Filter is stated to be of high value. The filter is also applicable to the treatment of refuse liquid and solid matter of any kind discharged from factories, chemical works, etc., etc.

In Mr Edwin Chesshire's patented system, the object is to keep the solid excreta apart from the liquid, the solid being treated so as to render it fit for a manure as used in the ordinary way. The liquid portion of the excreta is to be separated from the solid at the fountain-head, and, with the ordinary water of the closet—if a water-closet be used—is filtered through charcoal, and then passed into drain-pipes, placed above or at the side of the ordinary street sewers, and finally utilised for the irrigation of land. The liquid portion not being mixed with rainfall will be therefore much less in quantity and richer in quality than the town sewage under ordinary circumstances.

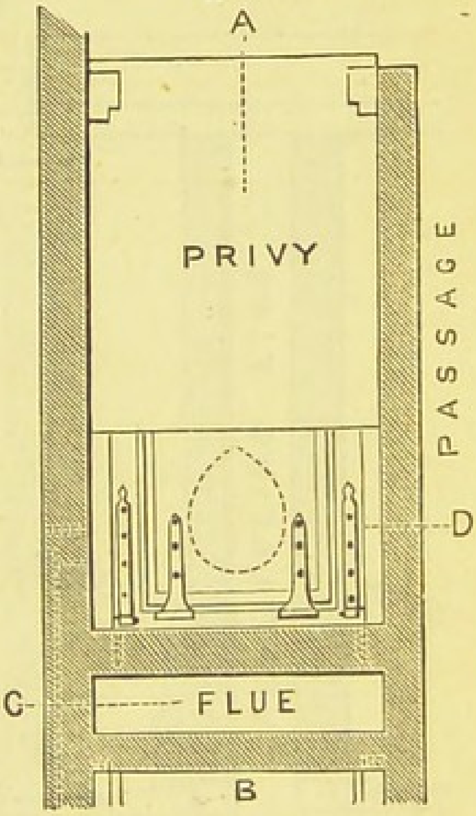
Another method proposed under the present head, is what is known as Liernur's Pneumatic System. In this, the excreta mixed only with the water of the water-closet—if this be used—are kept apart from the rain-fall, and the liquids from domestic and manufacturing operations. The privies are connected by pipes to a central reservoir or tank, placed under the pavement of the street. These tanks or reservoirs are made of wrought-iron plates, strong enough to resist considerable atmospheric pressure. Each privy-pipe is provided with a valve, by which the communication between the reservoir and the privy or closet can be cut off when required. The tanks are emptied by means of atmospheric pressure, and are proposed to be so emptied at night. A portable or locomotive steam-engine, with appropriately designed air-pump, etc., is brought up to the tank, the pump is set to work, to form a vacuum in the tank, the valve on the pipe connecting it with the privy is then opened, and by the atmospheric pressure the contents—liquid and solid—are then forced into the reservoir. The reservoir is then emptied by the same principle, the contents being forced into a receiver, placed in connection with the locomotive engine. The plan is a modification of that which was used, and is, we believe, still used, in Paris, in some districts, for the emptying of the cesspools. While possessing many features worthy of notice, and while no doubt yielding for farming purposes a manure much more valuable than ordinary town sewage, it is obviously, we think, difficult to be carried out on the large scale, where it would be of necessity "costly and cumbrous," to quote the words of the Birmingham Sewage Report.

The last method to be noticed under the separate system of treatment of the excreta of houses in towns is a modification of the old open midden or ash-pit and privy system, alluded to in the early portion of the present chapter, and which is now being carried out at Manchester and Rochdale with such success that, as we shall presently see, the town of Birmingham is about to follow up the plan, or a modification of it, in the treatment of the excreta of their large population.

In the large and densely populated city of Manchester, the local peculiarities rendered an adoption of the water-closet system on the complete scale, as in Liverpool, a practical impossibility, not merely from the fact that the necessary supply of water could not at any cost be obtained, but because there was no river near into which the sewage could be discharged, without making it absolutely intolerable from its filthy condition, a condition bad enough at the best under ordinary circumstances. A modification of the "midden and privy system," universally used in the city, was therefore necessitated, this being illustrated in Fig. 62, which is a plan, Fig. 63, a part section on line *a b* on plan, and in Fig. 64, which is a section on the line *c d* in plan. The following is the description which Mr Leigh of Manchester gives of this :

"It consists of a common privy, with a small covered ashpit, from the top of which a ventilating shaft is taken to the roof of the house to which it is attached. The floor of the ashpit is of glazed earthenware, absolutely water-tight, and its door, which is either at the side or back, is kept locked, and only opened by the night-soil men when they come to empty it. The ashes can only be emptied into the ashpit through the privy seat (which is provided with hinges, and can be raised entirely for this purpose), and must of necessity be poured over, and thus deodorise the fæcal matters.

Fig. 62.

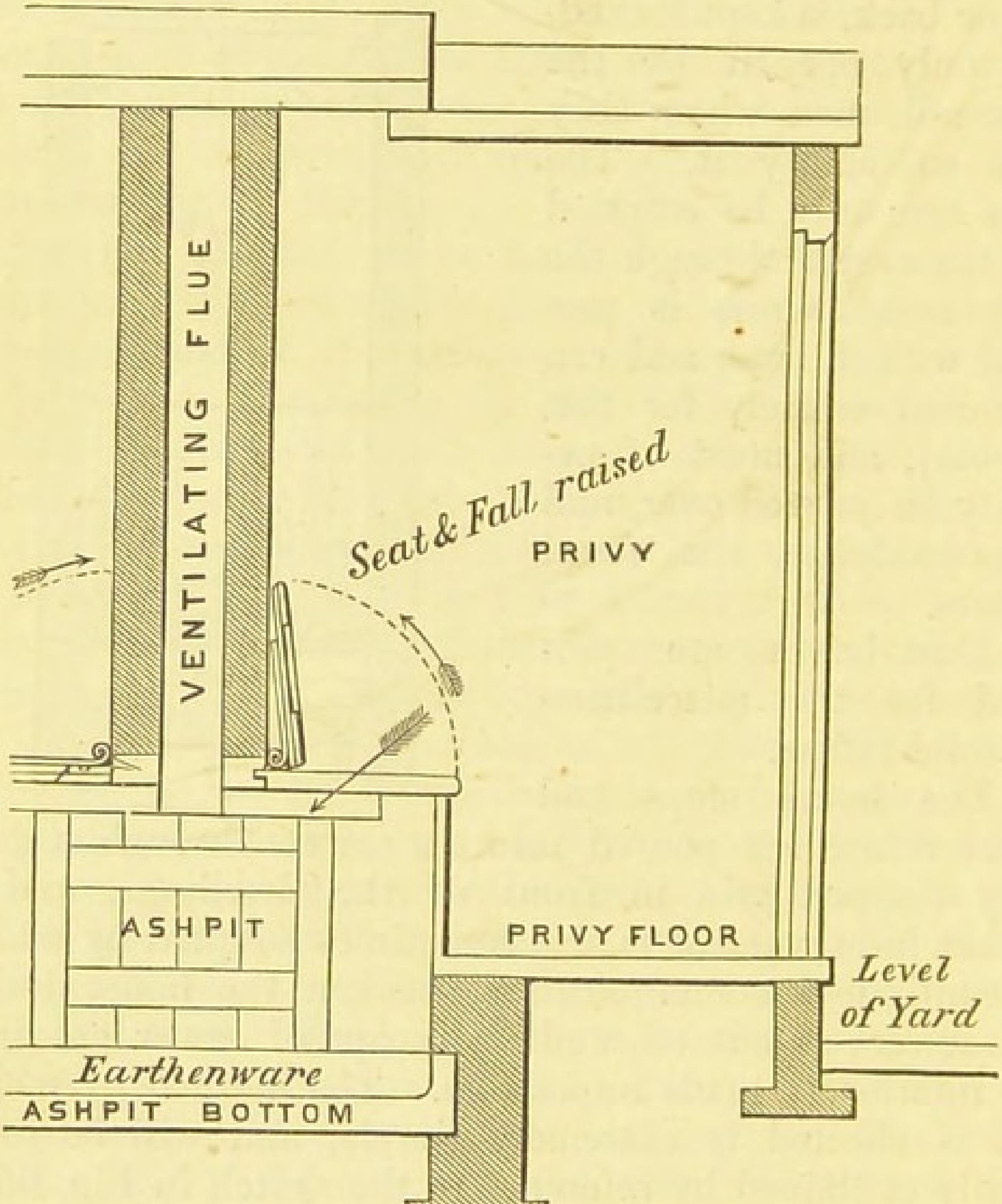


"Dust-boxes are provided for the miscellaneous solid refuse.

"The house slops and liquid refuse are poured into the sewers through a properly trapped grid in front of the dwellings, and a further improvement is also sometimes adopted by which all continuous communication between the house drains and sewers is cut off, and an escape of sewer gas into the interior is made impossible. The method by which this is effected is extremely simple, and will be most readily explained by reference to the sketch in Fig. 65.

No special means are taken to ventilate the sewers, as in Liverpool. Such ventilation as has been arrived at, is effected by the down-spouts of the houses, and by street gratings left open for the purpose. The "fall" of the sewers and the consequent discharge of the sewage being so rapid, no flushing, as a regular system, is carried out, although it is occasionally done. The escape of sewage gases from the interior of ordinary drains to those of the houses with which they are connected, is prevented by an

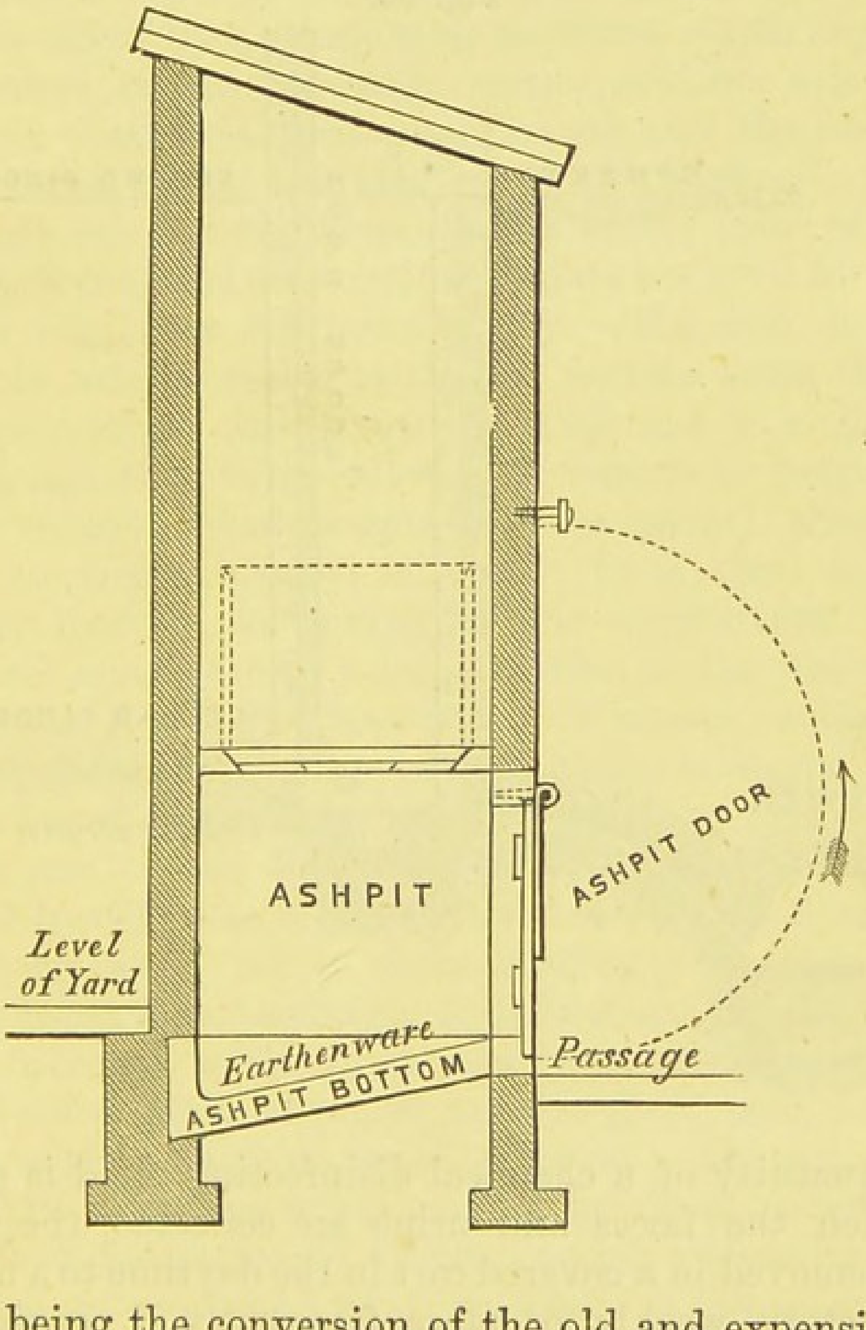
Fig. 63.



arrangement illustrated in Fig. 65. In this the sewer is brought up to the outside wall of the house, connecting it at that point by a trapped grating, on the top of which grating the house drains discharge their contents. This system is being now introduced into Manchester.

The system adopted at Rochdale proceeds much upon the same principle as that used in Manchester, the

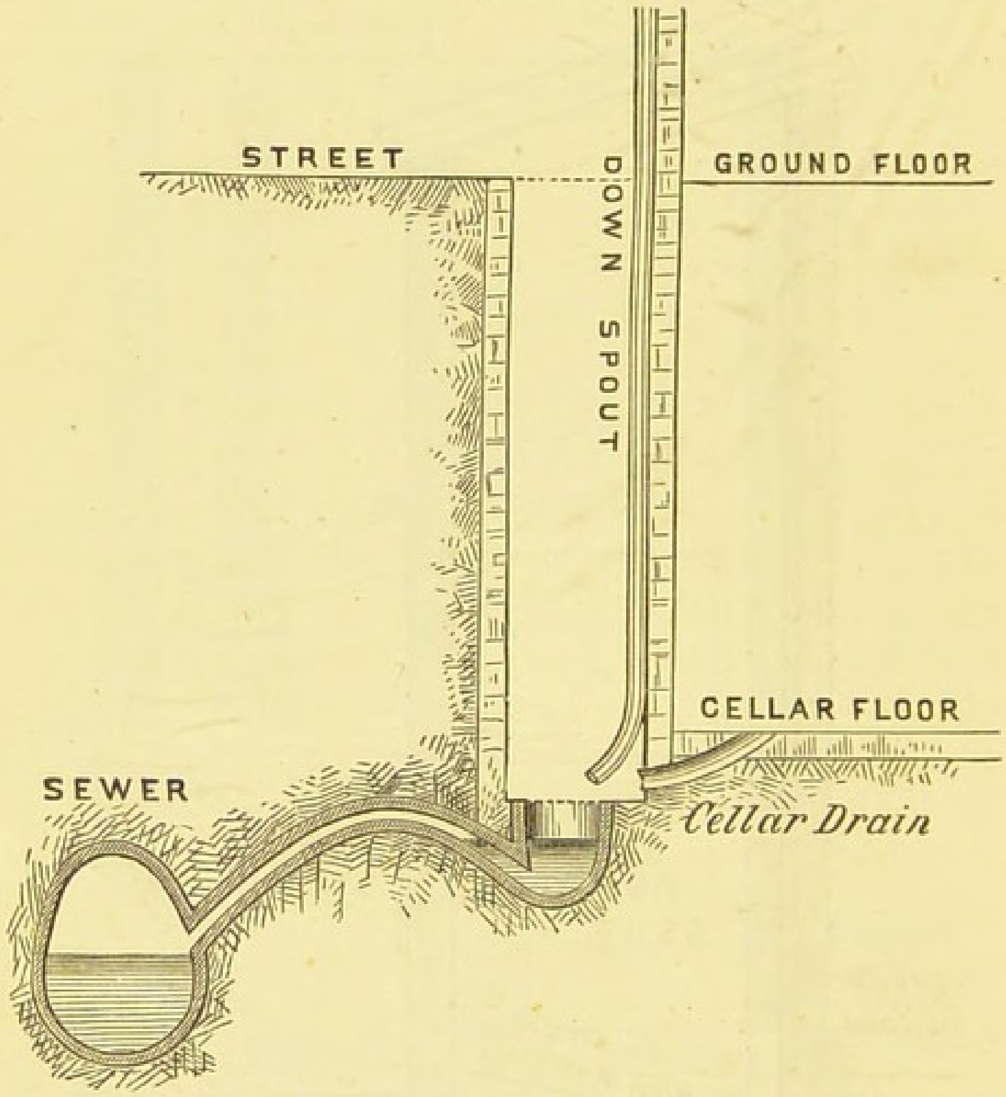
Fig. 64.



object being the conversion of the old and expensive system of middens and privies into privies calculated to promote health and decency, and to keep out from the sewers as much of the excremental matter of the population as possible. The following is a description of the system, as prepared for the Birmingham Sewage Inquiry Committee by Mr Alderman Taylor of Rochdale:

"Beneath each closet seat a receptacle, containing a

Fig. 65.



small quantity of a chemical disinfecting fluid is placed, in which the fæces and urine are collected, the vessels being removed in a covered cart in the daytime to a manure manufactory, weekly, or more frequently if required, an important feature of the process being a retardation of fermentation of the excreta, so as to prevent it from foul-ing the atmosphere and being depreciated in value as a manure, which is effected by frequent removal of the receptacles prepared as above stated. The cinders and dry refuse from the houses are in like manner collected in common barrels or other receptacles, and when full the contents are tipped into a corporation cart and removed to the same depôt or manufactory as the excreta, where they are sifted by a winnowing machine, which separates the cinders, refuse, vegetable matter, and fine ash. The vegetable matter is burnt, and its ash and the fine coal ash are used in the manufacture of the manure. There is a ready sale for the large cinders at the price of three shillings a ton, and the smaller cinders are used for working the engine at the manufactory. The fine coal and vegetable ash is mixed with the excreta from the prepared receptacles, the mixture is subjected to a chemical process, and after being allowed to remain in heaps for a period of about twenty-one days, is passed through a screen to ensure perfect mixing. It is then a damp powdery manure, containing all the constituents of the fæces and urine, except a large portion of the water. By this process a valuable manure is produced, which will allow of the addition of several valuable manurial agents if it be found desirable; but such addition is not necessarily a part of the process. By this method of collecting and treating the night soil and refuse of towns there is nothing lost; all is made profitably available, the cinders being found sufficient to raise steam for any motive power required in the process of preparing the manure, and all other kinds of refuse, such as glass, iron, etc., can be disposed of for their usual purposes. The urine from the public urinals and that portion which can be collected from dwelling-houses, to which is added a quantity of the same before-mentioned mixture, which is put into the receptacles for night soil, is evaporated and added to the prepared manure. The blood from the slaughter-houses is also, by a simple and inoffensive process, brought into a state fit to be added to the prepared manure, and forms a valuable addition to it.

"The privies on this system, inspected by the committee, were found to be perfectly clean and inodorous; and the abolition of middens and separate utilisation of the excreta and ashes appeared to them to be a great sanitary and economical improvement."

As already alluded to, the treatment of the sewage of the large and important town of Birmingham is attracting considerable attention, not merely from the discussion to which the bill for carrying out the proposed system has given rise in Parliament, but from the important influence the example will have in the future phases of the question of the disposal of the sewage of large towns and cities. The Corporation of Birmingham have spared neither expense nor time in endeavouring to come to a right conclusion as to what was the best course to take under the circumstances in which the town is placed. They appointed a committee, with full powers, to investigate the whole subject, to visit other towns and districts from which some experience could be gained, and to receive reports from scientific men, engineers, etc., who have devoted their attention to it, in one or more or all of its phases. The labours of the committee in the above directions have resulted in their collecting a vast amount of practically useful information on the subject, and which is embodied in a report just issued, and to the pages of which we have been indebted, as the reader will have perceived, for much information. In this report the committee recommend a scheme which is based upon the general conclusions to which they have come, these being as follows:

"1. That the midden system of collecting excreta in the densely populated districts of towns is universally condemned on account of the pollution of the earth, air, and water in their vicinity which is its inevitable result, and that it is essential to the health, cleanliness, and comfort of the inhabitants of such districts that all fæcal matters should be removed with the greatest possible despatch. 2. That this can be effectually done either by the water-closet system, as at Liverpool, or otherwise by the Rochdale, Manchester, or other systems, which not only secure a rapid removal of these matters, but effectually exclude both their solid and liquid constituents from the sewers. 3. That some such system as the Manchester and Rochdale system is being largely introduced in preference to an extension of the water-closet system, where there is a difficulty of dealing with the sewage at the outfall. 4. That the Rochdale system appears preferable to the Manchester system, because it deals separately with the excreta and dry refuse, and renders possible the most perfect and economical utilisation of each. 5. That the refuse from slaughter-houses, public urinals, and cattle markets may be advantageously collected and utilised. 6. That where structural alterations or special modes of building are required, it is found most convenient to have them carried out through the special and stringent powers of a sanitary committee or medical officer of health." As will be seen further on, part of the scheme is the "downward intermittent filtration system."

The recommendations are, it appears, now to be carried out, the Corporation Bill having passed the first reading in the House of Commons.

Well adapted as the Rochdale and Manchester systems, now described, may be to towns such as Birmingham, and indeed to the majority of the towns of England, where the houses, however, humble, are all "self-contained"—that is, where each house is perfectly independent of its neighbour, even although the houses may be built in rows or streets, it is obvious that it is totally inapplicable to towns such as those in Scotland, where the houses are built on the "flat" system—that is, where the buildings are constructed in storeys, each storey being a separate house, or even forming two or more houses, all being entered from one staircase, called a "common stair" in the north. In England, houses with yards, in which a privy is almost always placed, even although the house should itself contain a water-closet, are the rule; in Scotland, decidedly the exception. The difficulty of the disposal of the excreta of Scottish towns cannot therefore be overcome by the adoption of the Manchester, Rochdale, or even the Liverpool systems, above described, the circumstances being altogether different from those where the yard or outside privy and midden system is prevalent, as in so many towns in England.

We now come to consider briefly the second method of attempting to deal with the great difficulty in the way of the disposal of town sewage, presented by the vast quantities of water with which it is diluted—namely, the precipitating processes." These processes have a double object in view—first, the detaining of the solid refuse of the sewage, to be used in a separate form as an ordinary manure; and second, so purifying it that the affluent liquid may be sent into the streams and rivers without polluting them. A great number of plans have been tried under this head, but the general result seems to be that the obtaining of solid manure from liquid sewage is next to impracticable. On the one hand, in support of this view, we have the evidence of a very great number of trials which have been made to obtain a valuable manure in this way, all of which have failed in giving thorough satisfaction; while, on the other, we have the evidence of the analyses of eminent and trustworthy chemists, pointing to the same result, all of whom agree in stating that if town sewage is to be applied to land generally, it must be applied in its normal state—that is, in the liquid form. Professor Way has stated unhesitatingly, that any existing plan for the production of solid manure from sewage water would be a failure. He says this from a knowledge of the fact, that of the valuable matters contained in sewage water, nine-tenths exist in a liquid state; and these could not be separated by any known process of filtration, nor could they be precipitated by any substance which they had at present at command.

Where the processes under this head are so numerous, it is on the one hand manifestly impossible within our limits to notice them all, however briefly, nor indeed does the scheme of our work necessitate this being done; while on the other, it would appear invidious to select for notice a few out of many, where all claim precedence for their plans; still we run this latter risk, and describe in briefest fashion the two which are at once the newest, and most highly thought of by many. The first of the precipitating processes which we notice is that known as Dr Forbes's Patent, which has been highly spoken of by scientific authorities—Dr Voelcker, chemist to the Royal Agricultural Society of England, amongst others, having reported favourably of it. The distinguishing feature of this process is the employment of a material which, while it acts as a disinfecting agent, possesses also highly valuable fertilising properties. The agent employed is the phosphate of alumina dissolved in hydrochloric acid. Acting at once as a powerful disinfectant, and adding to the fertilising value of the clarified and purified sewage, it adds in like proportion to the value of this as an irrigating fluid. The deposited solid being disinfected to a very satisfactory extent, is made up as a solid manure with much less offensive manipulation than is the case with other processes of precipitation.

The second process is that known as the "A B C," and to which a large amount of public notice has been attracted by the energetic working of the company organised for the purpose of bringing it into general use. The highest degree of efficiency has been claimed for it, and to the Company at all events the merit is due of basing their chances of being paid for their risk in many instances on the efficiency of the plan. They are now, for example, at Leeds, undertaking the treatment of the sewage, paying the corporation 5 per cent. on their outlay for erection of works, and giving them also 15 per cent. of the net profits from the sale of manures. The plan is also being carried out at Bolton, the company agreeing to take as a royalty, for the use of their patents, 25 per cent. of the manufactured manure. So much doubt, however, has been thrown upon the effectiveness and economy of the process by eminent authorities, especially the River Pollution Commissioners, that the Corporation of Birmingham, which will henceforth stand forward as the Public Body which has done most to ascertain the whole bearings of the question, have not felt themselves justified to attempt to deal with their sewage by this process. The process, patented by Mr Sillar, consists in thoroughly mixing the sewage with certain proportions of alum, blood, clay, and charcoal, and certain other substances, allowing the mixture to remain quiescent for a time, till solid matter is deposited. The affluent water, more or less purified, is allowed to run off in the sewers or river, while the solid matter is manipulated and dried, and is then ready to be sold as a manure.

We now come to the third plan by which the great dilution of sewage with water is proposed to be avoided —that is, by having two distinct sets of drains, one to convey away the excretal sewage to land to be irrigated by it, or to be treated by the precipitating process ; the other set of drains to convey the storm and rain water to the rivers. This was first proposed, and many years ago, by Mr F. O. Ward, but is now better known as the "Menzies system," from its having been practically carried out by Mr Menzies at Eton. There can be no doubt that if, as one able authority puts it, "the rainfall could be excluded from the sewage proper, a vast step would be gained towards the practicability of usefully applying sewage." But however desirable this modification of the present system may be, such are the difficulties in the way of carrying it out, that there seems little likelihood of its being adopted, the scheme involving, as will be seen, a double set of drains and sewers. This, however, is but one of the many difficulties which environ the project. Thus, for instance, a very important objection is met with—important in its results, if Mr Chadwick's statement be correct—namely, that town sewage owes much of its fertilising powers to soot, as from the roofs of houses, and to manure, as from the roads. If so—but this is much disputed—then it is evident that this source of increased value is cut off so soon as the plan of keeping the rainfall separate from the sewage is carried out.

The following is a description of the fourth system of treating town sewage—namely, the filtration process: "The object in view—considering simply the purification of sewage—is to arrest the suspended matter, and to subject all the organic matters, both suspended and dissolved, to a rapid process of oxidation; in fact, to convert the carbon of organic matter into carbonic acid, and the nitrogen into nitric acid and ammonia, all of which are soluble and inoffensive in water—at any rate so far as that water with these only in solution may be safely admitted into a running stream. In other words, the object is to determine the decomposition, so as to bring the organic constituents as rapidly as possible into the forms they would ultimately assume if they were left to decompose spontaneously. The free oxygen always contained in the water of a running stream, in process of time, effects the decomposition and conversion of organic matter into the compounds—carbonic acid, nitric acid, and ammonia; and this conversion, combined with the subsidence of suspended matters, gradually purifies any river into which sewage may have been discharged."

The filtration processes—strictly so called—which have been introduced to public notice, are pretty numerous. One to which attention has been much directed is that worked by the Peat Engineering and Sewage Filtration Company (Mr Weare's patent). The filtering materials used in Weare's process are charcoal and sifted cinders. There is, we need scarcely say, great diversity of opinion as to the efficiency of this system, and the economy with which it can be carried out. The Corporation of Bradford are about to treat their sewage upon it; they are erecting the necessary works at their own cost, the company working the patent taking the sewage and undertaking purification.

If the reader has followed us thus far, he will have come to the conclusion, if he had not, by a study of all its phases, previously come to it, that the question of this town sewage how best to treat and utilise it, is what we at the outset of its discussion stated it to be, one surrounded with many difficulties. If in connection with the one scheme, out of the many schemes brought forward to settle these difficulties, which seems from the evidence obtainable to be that the least surrounded with difficulties, namely the utilisation of sewage by using it for irrigating land, the opinions of chemists and agriculturists are, to use the words of the Birmingham Sewage Report, "absolutely" and irreconcilably conflicting, what chance is there of a definite opinion being framed upon such conclusions come to as to the working out of the other and various schemes we have, and the still more numerous ones we have not, described? How then are corporations to get out of the difficulty in which they are placed? If, on the one hand, the legislature insists as—if the proposed law which is now under discussion in the House of Commons be passed—it will insist, upon their getting rid of this sewage as a sanitary nuisance without passing it in its normal condition into the rivers; they are told, on the other hand, that scientific men are far from being agreed as to whether there is as yet any one plan in existence by which the sewage can be otherwise treated, so as not to be a nuisance, clearly either way they are upon the horns of a dilemma. There is, however, a gleam of hope in a direction only very recently pointed out, and this is by the adoption of a modification of the filtration system which we have just described; the main features of this will be gathered from its name, the "intermittent filtration system." We have seen that while it is admitted that the best way yet proposed by which we can utilise town sewage is to irrigate land with it for the growing of various crops; still, the difficulties attendant upon the getting of the requisite quantity of land for this purpose in the neighbourhood of *large* towns are so great, and the expense, moreover, of preparing the land so enormous, that practically the system is put out of court as impracticable in such cases. This the Birmingham Corporation unhesitatingly declares to be the result of their investigations into the whole subject. The question, therefore, which was absolutely forced upon those most deeply interested was, is there no way of modifying the irrigating system, so far that the sewage may be purified—*that* being considered the primary thing to be aimed at by corporations, as we have always maintained—by the use of a less quantity of land, although that may not be enough to get the fullest advantages out of the sewage agriculturally? There is a growing opinion amongst scientific men, that the question is likely to be answered favourably by the intermittent filtration system. This, in few words, may be described as applying the sewage to a limited area of land, allowing it to pass through the soil, and from it in a purified condition into the river, which is to be the ultimate outlet; it is, in fact, filtration through soil—alluded to in pages 171, 173 of this work—on the large scale. The filtration is not continuous, but as the name of the system implies, is only carried on at intervals in the same soil, the area of land selected being divided say into four equal portions, each portion receiving the sewage for say six hours, thus receiving a "rest" of eighteen hours out of the twenty-four. As stated at p. 231, in using sewage for irrigating land on the system usually adopted, it has been estimated that an acre of land is required for every 20 to 25 persons of the population; some authorities, however, put it higher than this, going up to 40 to 60 persons per acre. With either estimate, however, a very large extent of land is required for irrigation on the ordinary plan, but with the "intermittent filtration" system it is admitted that an acre would purify the sewage of from one to three thousand persons, according to circumstances, of locality, soil, etc. If the system on an extended scale turns out as successful as it has up to the present time turned out successful in the small scale yet tried—notably, at Merthyr Tydvil—it is evident that it gets rid of the great difficulty of obtaining land in the neighbourhood of large cities. The River Pollution Commissioners admit that sewage liquid can be "effectually purified" by this system of intermittent filtration, and that "probably any variety of porous and finely divided soil may be employed for this purpose;" but they fear that the collection of fæcal matter on the surface of the land, as one result of the process, will be the creation of a nuisance, especially in hot weather, and they decidedly give their opinion that it will be "entirely unremunerative," as the quantity of the sewage applied to the area of land will be too great to admit of any ordinary agricultural crop being grown upon it; deducing from this their next objection to the system, that the manurial ingredients of the sewage would be "absolutely wasted."

Acting, however, under the advice received from eminent authorities, the Birmingham Corporation, if not making light of the above objections, certainly act as if they were not very valid; for they are about to apply the system as part of their scheme for treating their town sewage. Five hundred acres are to be set aside for this purpose, divided into three areas, "any one of the three being sufficient to receive the sewage for six or twelve months, as may be decided upon, leaving the others at rest." Part of the sewage, as it flows from the town to the filtration areas, will be disposed of at certain points to those farmers in the neighbourhood who may wish to use it for their crops; and it is further intended to establish a small model sewage farm to instruct the neighbouring farmers in the use and value of sewage as a manure. As regards the chances of the system of intermittent filtration paying, Mr Bailey Denton—the well-known agricultural engineer, who has charge of the Merthyr Tydvil works, where 400 acres are used to treat the sewage of 50,000 persons, equal to a daily flow of 600,000 gallons—gives it unhesitatingly as his opinion, that with proper management the system will give a pecuniary result, as "great, if not greater, than that obtained from irrigation."

Such then is the present position of this "vexed question," and such are brief expositions of the latest attempts to test its solution on the largest scale. To the Corporation of Birmingham is due the high honour of being the first to lead the way in legislating upon the question in a thoroughly common sense way. Going to the full consideration of it, with no preconceived notions of their own, as to how the problem before them was to be solved; determined to be led aside from their straightforward inquiry by no specious appeals, come from what quarter they might, in favour of any scheme however highly recommended; anxious to receive testimony from all parties, to hear all that could be said about, to see nearly all that could be seen in connection with, the subject; they have collected a large amount of practical information upon all its branches. If they had done only this, they would have rendered the general community a service of vast value; but they have done much more; they have come to a conclusion as to a course of action which we believe to be accurate in the principle upon which it is based, and the practical carrying out of which will tend, in no small measure, to get rid of the difficulties which have up till now environed the subject. These difficulties have in great measure arisen from a determination to carry out foregone conclusions, and from overlooking the facts that no one system is universally applicable, that what may do for one town will not do for another, and that what was set down too eagerly as "axioms" in the science of sewage, were not axioms at all, being based upon "facts" which, although honestly obtained under one set of circumstances, would have been found, and have been found, not to be obtainable from experience under other circumstances totally different.

It would be well, therefore, for the advancement of this department of sanitary science, if corporations of other towns, who are troubled with the sewage question, would set about the solution of the problem connected with it in the same spirit, and carry it out in the same practical, common-sense way, which has distinguished the Corporation of the large and wealthy town of Birmingham.

To the Report they have issued, we have the fullest confidence in directing the reader, desirous to get fuller information on the subject than our space has been able to afford him. It contains much matter that is highly valuable; and the "conclusions" which the Corporation have come to, are set forth in a way, and in language which stand out in marked and favourable contrast to some Reports which have passed through our hands.

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THE END.