ON THE

SMOKELESS FIRE-PLACE,

CHIMNEY-VALVES,

AND OTHER MEANS, OLD AND NEW,

OF OBTAINING HEALTHFUL WARMTH AND VENTILATION.

BY

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NOTICE.

The Author, some years ago, published a brief Treatise on Warming and Ventilating, in which he gave an account of various forms of self-regulating fires. It aroused in a remarkable degree the attention of Manufacturers to the subject of their Stoves and Fire-places, and many patents for supposed improvements were soon enrolled; but the knowledge of the scientific principles, from which alone correct procedure could spring, was not generally possessed, and many errors were committed. The Author's professional engagements did not allow him at that time to publish more on the subject, and he waited until his intended retirement from active professional duties should enable him to repeat and extend his lesson. This work is his present offering.

PREFACE.

THAT in the last fifty years of the world's existence more important advances have been made in the arts of civilization than in any five centuries before, can scarcely be doubted by one who considers that within that time have sprung up—the application of Steam Power, itself a recent invention, to Railways and Navigation—Gas-lighting—the Electric Telegraph—Photography, or sun-painting—the Penny Postage, and other things. There is no reason for thinking that this progress is at an end. On the contrary, as clear-sighted men had long foretold the accomplishment of most of the results enumerated, before the popular mind had yet dreamt of the possibility of such wonders—so now are scientific men pointing to the quarters from which other novelties worthy to be added to the list are likely to come.

The fact that the principal of the results above-named are dependent, directly or indirectly, on the action of fire, while the store of coal existing in the world is limited, and where once diminished or exhausted, will never be replaced; and the fact, well ascertained, that at present, in the ordinary modes of using fuel, much less than half of the heat produced is turned to use—and, therefore, much more than double the quantity of fuel really required is consumed; and, lastly, the fact, that in the common attempts to obtain from fire, comfort and security to health in cold weather, very hurtful as well as expensive errors are committed—all these point to the subject of management of combustion as one in regard to which new triumphs may be won; not, indeed, splendid and striking as those classified above, but not of inferior importance to any of them.

The author's intention by the present work is, first, while publishing some original views and devices, for which the Council of the Royal Society of London have awarded him an honorary medal, to awaken the clear intelligence of his countrymen and countrywomen to the true importance of the subject, that they may aid in working out and establishing improved methods of using the wealth of the coal-mines, the existence of which in extraordinary abundance is one of the most precious distinctions of their favoured land.

Another end here aimed at, is to arouse public attention sufficiently to the fact, still very imperfectly comprehended by the popular mind, that what is commonly called an "empty room" is a room as truly filled with fluid air—part of an ocean of known depth which covers the earth—as an open vessel at the bottom of the sea is filled with fluid water; and that the life of a man does not more certainly depend on his inhaling a given bulk of that air, about twenty times in every minute, than his health depends on his breathing air which is pure. Then, as air once breathed acts as poison if breathed again, and as many other causes are defiling and vitiating the air where men live and work, there must be, wherever air is confined by walls or otherwise, some fit means of changing it—that is to say, of effecting ventilation.

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THE SMOKE-CONSUMING AND FUEL-SAVING FIRE-PLACE,

WITH ADJUNCTS INSURING THE HEALTHFUL WARMING AND VENTILATION OF HOUSES.

THE great evils connected with the common coal-fires are :—

1. Production of Smoke.
2. Waste of Fuel.
3. Defective Warming and Ventilation of Rooms.

1. SMOKE IN THE INTERIOR OF HOUSES AND IN THE EXTERNAL ATMOSPHERE.

The jocular proverb which declares a smoky chimney to be one of the greatest troubles of life may serve to recall the annoyances endured within rooms where the chimneys do not perform their office aright. To judge of the evils produced by an external smoky atmosphere, the following particulars may be noted. It is ascertained that in London alone, on account of its smoke-loaded atmosphere, the cost of washing the clothes of the inhabitants is greater by two millions and a half sterling a-year (that is, by twenty-five times one hundred thousand pounds), than for the same number of families residing in the country. This, however, is seen to be but a small part of the expense when we consider the rapid destruction, from the same cause, of nearly all furniture in houses, as carpets and curtains, of articles of female apparel, of books and paintings, of the decorations of walls and ceilings, and even of the stones or bricks of which edifices are constructed. Then for personal cleanliness it becomes necessary to be almost constantly washing the hands and face. Flowering shrubs and many trees cannot live in the London atmosphere, so that the charm of a garden, even at considerable distances from town, has almost ceased with the extension of the buildings and increase of smoke: a growing flower, if exposed to the atmosphere, is always covered with blacks or sooty dust, and defiles the hand which plucks or touches it. Sheep from the country, placed for a few days to graze in any of the parks, have soon a dingy fleece, making strong contrast with that of others newly arrived and mixed with them. And this atmosphere, so damaging to inanimate things and to vegetable life, is inimical also to the health of man, as proved by numerous facts recorded in the Bills of Mortality. Persons with certain kinds of chest-weakness cannot with comfort reside in London. Many children brought from the country are soon observed not to be thriving. The coal-smoke, then, may be called the great nuisance and opprobrium of the English capital.

2. Waste of Fuel.

Count Rumford, a writer of great authority in such matters, after making elaborate experiments, declared that more than five-sixths of the whole heat produced in an ordinary English fire goes up the chimney with the smoke to waste. This estimate is borne out by the facts observed in countries where fuel is scarce and dear, as in parts of Continental Europe, where close stoves are used to prevent the waste. With these about a fifth part of what would be consumed in a common open fire, suffices to maintain the desired temperature. To save a third part of the coal burned in London alone, would save more than a million sterling a-year; and when coal is very dear, as during severe winters, the saving would be much greater.

Then it is to be considered that coal is a part of our national wealth, of which, whatever is once used can never, like corn or any produce of industry, be renewed or replaced. To the existence of coal-mines in Britain is probably due the invention here, and the rapidly extended use of the improved steam-engine of modern time, through which the condition, not of Britain only but of the whole world has been so signally advanced. To consume coal wastefully or unnecessarily, then, is not a slight improvidence, but a serious crime committed against future generations.

3. Defective Heating and Ventilating in Dwellings.

Since London attained its present magnitude, about a thousand a-week has been the average mortality; but during severe winters the cold and its consequences increase that weekly mortality by six or seven hundred, proving that against the cold, the existing arrangements for warming and ventilating are insufficient. That not a little of the premature mortality at all times, and of the spread of epidemics, and of the low condition of health among the people, is owing to the same causes, will be rendered apparent in future pages.

We shall now inquire whether it be not possible in a great measure to avoid the three great evils above described, and by means which at the same time shall secure still other advantages.

1. Smoke.—Is it possible to avoid or to consume smoke—in other words, to produce a smokeless coal-fire?

Common coal is known to consist of carbon and bitumen or pitch, of which pitch again the chief element is still carbon, joined then with hydrogen, a substance which, when separate, exists as an air or gas.

When the coal is heated to a temperature of about 600° degrees Fahrenheit, the bitumen or pitch evaporates as a thick, visible smoke, which, as it afterwards cools, assumes the form of a black dust or flakes, called blacks, or smut, or soot. If pitchy vapour, however, be heated still more than to 600°, as it is in the red-hot iron retorts of a gas-work, or while rising through a certain thickness of ignited coal in an ordinary fire, its elements combine in a new way and are resolved in great part into invisible carburetted hydrogen gas, such as we burn in street lamps.

Now when fresh coal is thrown upon the top of a common fire, part of it is soon heated to 600°, and the bitumen of that part evaporates as the visible smoke immediately rising. Of such matter the great cloud over London consists. Whatever portion of the pitchy vapour, however, is heated to the temperature of ignition by the contact of flame or ignited coal, suddenly becomes gas, and itself burns as a flame. This is the phenomenon seen in the flickering or irregular burning of gas, which takes place on the top of a common fire.

But if fresh coal, instead of being placed on the top of a fire, where it must emit a visible pitchy vapour or smoke, be introduced beneath the burning, red-hot coal, so that its pitch, in rising as vapour, must pass through the burning mass, this vapour will be partly resolved into the inflammable coal-gas, and will itself burn and inflame whatever else it touches. Persons may amuse themselves by pushing a piece of fresh coal into the centre of the fire in this way, and then observing the blaze of the newly-formed gas.

Various attempts had been made to feed fires always from below, and so to get rid altogether of smoke. One of the first recorded was made by Dr. Franklin. He placed the burning fuel in a cage of iron bars supported on pivots, and when part of the fuel was consumed, leaving the upper part of the cage empty, he filled the vacant space with fresh coal, and immediately turned the cage upside down, so that the new smoking coal was underneath, sending its pitchy vapours upwards through the mass of ignited coke. Another attempt was made about thirty years ago, by an ingenious manufacturer in London, Mr. Cutler. He placed a box filled with coal under the fire, in which box there was a moveable bottom, by raising which the coal was lifted gradually into the grate to be consumed. The apparatus for lifting, however, was complicated, and liable to get out of order, which, with other defects, caused the stove to be little used.

The moveable bottom rested on a cross-bar of iron, which in rising was guided by slits in the side of the coal-box, and was lifted by chains at each end, drawn up by a windlass, and this windlass was turned by bevel wheels, of which one had to be moved by a winch in the hands of an attendant. Mr. Cutler took out a patent for his apparatus, but a trial at law afterwards decided that he had no patent right.

In the new fire-grate here to be described the consumption of smoke is only one of several equally important ends obtained by a construction of much simplicity. A skeleton sketch of the arrangement is given in the accompanying wood-cut. The charge of coal for the day is placed in a box immediately beneath the grate, as shown in the diagram at the letters *e f g h*, and is borne upwards, as wanted, by a moveable false bottom or piston, *s s*, in the box, raised simply by the poker used as a lever, as the wick of an argand lamp is raised by a screw; the fire is thus under command almost as completely as the flame of a lamp. There are notches in the piston-rod *m n*, to admit the point of the poker, and the ratchet-catch, *i u*, to support the piston at any desired height when the lever is withdrawn.

The coal-box of this fire-place, that it may receive a charge of coal sufficient for the whole day, must be from eight to ten inches deep, and will contain from twenty to thirty pounds, according to the area of grate. In winter an inch or two more of coal may be added over the mouth of the box before the fire is lighted, and in warmer weather the box will not require to be quite filled—that is to say, the piston at the time of charging will not have to be lowered quite to the bottom. When it becomes desirable

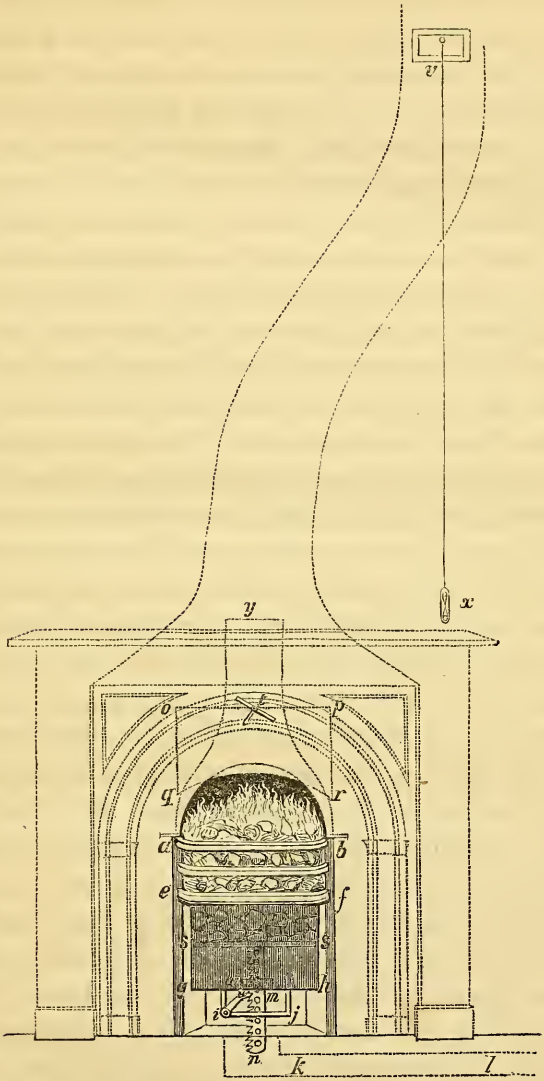


Fig. 1.

on any account, as will happen with kitchen-fires, and fires kept alight through the night, to replenish the coal-box while the fire is burning, this may be done almost as easily as to put coal on a common fire, in the following manner,—when the piston, or moveable bottom, has been fully raised, so as to have its flat surface level with the bottom bar of the grate *e f*, a broad flat shovel or spade, of the shape of the bottom of the grate is pushed in over the piston, and becomes at once a temporary bottom to the grate and a lid to the coal-box. The piston being then allowed to sink down to the bottom of the coal-box, and the spade or lid being raised in front by its handle, the coal-box is thereby opened, and a new charge of coal can be shot in. The spade being then withdrawn, the combustion proceeds as before. That the opening of this lid may be wider, the second bar of the grate, or the two bars together are made moveable, and yield upwards to the pressure of the spade.

This fire is lighted with singular ease and speed. The usual quantity of wood is laid on the upper surface of the fresh coal, in the box, and a thickness of three or four inches of cinder or coked coal, left from the fire of the preceding day, and having no smoky matter in it, is placed over all. The wood being then lighted, very rapidly ignites the cinder above, and at the same time the pitchy vapour from the fresh coal below, rises through the wood-flame and cinders, and becomes heated sufficiently itself to become flame, and so to augment the blaze. When the cinder is once fairly ignited, all the bitumen rising through it afterwards burns, and the fire remains smokeless. A fire-place supplied with coal from below was used by a distinguished engineer in town for ten years, and the fact that his chimney had not to be swept in the whole of that time, proved that no soot was formed.

In the new grate, because no air is allowed to enter at the bottom of the coal-box, owing to the piston-rod fitting accurately the opening in the bottom of the box through which it passes, there is no combustion below, but only where the fuel is exposed to air above, and near the mouth of the coal-box. The unsatisfactory result of some other attempts to make such a smokeless fire have been owing, in part, to the combustion extending downwards in the coal-box, because of air admitted below, and the consequent melting and coking of the mass of coal, so as to make it swell and stick, and impede the rising of the piston.

A remarkable and very valuable quality of this fire is, its tenacity of life, so to speak, or its little tendency to be extinguished. Even after nearly all the coal in the grate above the fire-box has been consumed, some air from above will dive into the coal-box and keep the fire there gently alight, burning from the top downwards like a torch, until nearly the whole contents of the box are consumed. Thus the fire will remain burning for a whole day or night, without stirring or attendance, and yet at any moment it is ready to burn up actively when the piston is raised; or when, by pressing the end of the poker into the mass, an opening is made for air to enter.

In certain cases, as during long nights, it may be desirable to insure the maintenance of the slow combustion with rather more activity, and for this purpose there is a slide in a small door at the bottom of the coal-box, by which a graduated admission of air may be allowed. That door itself is opened quite before lighting the fire, to allow of the removal of the coal-dust or ash which during the preceding day, has fallen down past the edge of the piston.

This fire is extinguished at night with singular rapidity, by lifting off a few pieces of the upper crust of the burning mass, and pressing close what remains, that air may not enter it. The morning charge should be such that enough cinder or coke may be left for the smokeless lighting of the next day.

With the means now described, then, the first-named evil of the *production of smoke* is effectually combated.

2. Waste of Fuel.—Can the *waste of fuel* which occurs in common open fires be prevented?

Count Rumford, as the results of his own experiments already referred to, declared that a great part of all the heat produced in a common open fire passed up the chimney with the smoke, and therefore to waste; and he appealed, in corroboration, to the experience of the Continent of Europe, where close stoves are used with great comparative saving. The writer of this has in his own house a striking illustration of the matter in a peculiar enclosed fire, to be described in another section, which, for fourteen years past, in a large dining-room, has maintained, day and night, from October to May, a temperature of 60° or more, with good ventilation, by an expenditure of only twelve pounds of coal for twenty-four hours, or about a fourth of what would be used in an open fire burning for fifteen or sixteen hours. The aperture by which enough fresh air enters this stove to maintain combustion sufficient to warm the room, is about three-quarters of an inch in diameter. If this be compared with the aperture of a common chimney-pot, which has a diameter of ten inches, and an area or size, therefore, more than 150 times greater than that of the stove, and if the rapidity be considered with which a column of dense smoke filling that pot escapes from it when the fire is burning briskly, and if it be considered further that such column consists almost entirely of the warmest air from the room, defiled by a little pitchy vapour from the fire, there is proof of prodigious waste, and room for reasonable hope that a great saving is possible. To see how the saving may be effected, the exact nature of the waste in such cases has now to be explained. A single mouthful of tobacco-smoke, on issuing from the lips to the air, immediately diffuses itself so as to form a cloud larger than the smoker's head, and if allowed, soon contaminates the whole air of a room, as happens with the smoke and smell of wood, paper, or other combustible burned in a room. Now the true smoke of a common fire is not, as many believe, the whole mass seen issuing from the chimney-top, but only little driblets or jets, which shoot up or issue from the cracks in the upper surface of the coal which forms the fire. These jets, however, quickly diffuse themselves, like the tobacco-smoke above referred to, in the air around them, that is to say, in the large volume which fills the space usually left over a common fire, and over the hobs, if there be such, at the side of the grate. The whole of the air so contaminated, and which may be in volume, twenty, fifty, or even a hundred times greater than that of the true smoke, or burned air, is then all called smoke, and must all be allowed to ascend away from the room that none of the true smoke may remain. It is evident, then, that if a cover or hood of metal be placed over a fire, as represented by the letters *y a b* in the diagram, or if, which is better, the space over the fire be equally contracted by brickwork, so as to prevent the diffusion of the true smoke, or the entrance of pure air from around to mix with it, except just what is necessary to burn the inflammable gases which rise with the true smoke, there will be a great economy. This is done in the new fire-place, with a saving of from one-third to one-half of the fuel required to maintain a desired temperature. In a room the three dimensions of which are fifteen feet, thirteen feet and a half, and twelve feet, with two large windows, the coal burned to maintain a temperature of 65° in cold winter days has been eighteen pounds for nineteen hours, or less than a pound per hour.

And it is to be remarked that not nearly the whole possible saving has been effected in the case referred to; for the true smoke, little diluted, is very hot air when it leaves the ignited coal, and if made to pass in contact with a vessel containing water, or a tube giving entrance to cold air, it will give up for use a considerable part of its heat. In many cases such saving may be profitably effected. With the present imperfect forms of open fire, the whole of the very hot smoke passes away as certainly as it does here, but is so much diluted with the tempered air of the room escaping to waste, that ordinary observers do not perceive, and, consequently, do not regret the loss.

In most cases the contraction of the space over the fire will be more conveniently made in the brickwork or setting of the grate than by a metallic hood. Where the hood is used, unless it be made a boiler or water-vessel, it should be lined with tile to prevent that overheating which might cause in the room some smell of heated metal.

The narrow part of the hood or brick channel passes through a plate or other stopping at the bottom of the chimney, so that no air shall enter the chimney but through the narrow channel; and there is a throttle-valve or damper in that channel at *t*, giving perfect control over the current of air which passes through. No part of the apparatus is more important than this valve or damper; and its handle or index must be rendered very conspicuous, and have degrees of opening marked on its plate as clearly as points are marked on a compass-card. When the valve is quite open, the chimney influence quickens the combustion, as in a blast furnace, or where a forge-bellows is at work, but by partially closing the valve, the air-current may be diminished, until only the most tranquil combustion remains. The valve should not be open in general more than just enough to let all the burned air, or transparent smoke, pass through. When the valve is once adjusted to the usual strength of chimney action, it requires little change afterwards.

In all cases it is as necessary to be able to command and modify, by a moveable plate or hanging door, *o p q r*, called a blower, the size of the front opening of the fire-place, as to command, by the damper-valve, the opening of the chimney-throat above. By the proper adjustment of the two, the rate of combustion and the desirable brightness of the front of the fire may be constantly maintained.

The chimney-flue immediately above the narrowed throat should have its sides made slanting, so as not to offer a resting-place for dust or any soot which, from careless use of the fire, might be produced. The size of the chimney-flue above is not important.

The answer, then, to the second question, as to the possibility of saving fuel, is by the facts here adduced, given in the affirmative.

3. Defects of Heating and Ventilating.—The third and last of the great evils of the present open fires is that there are great inequalities and deficiencies in their heating and ventilating actions, which faults bear powerfully on the public health. The hood and its damper, or corresponding formation of the brickwork, may appear, perhaps, as influencing these, to be of more importance than as saving the fuel.

First, as to the heating. The contracted chimney mouth and throat, by allowing so small a quantity of air to pass through in comparison with what rises in an open ordinary chimney, lessen in the same degree the currents or draughts of cold air from doors and windows, towards the fire, which currents are common causes to the inmates of winter inflammations and other diseases; and owing to the same construction, the heat, once radiated from the fire to the walls of the room, not being again quickly absorbed and carried away by such currents of constantly-changing cold air, remains in the room, and soon renders the temperature of the whole much more equable and safe.

A fact respecting the new grate, which to most persons becomes quickly apparent, is the extraordinary uniformity of temperature prevailing over the whole room, enabling the clerks in a public office, for instance, to sit and work at a distance from the fire as well as near it.

Still more completely to prevent cold draughts from falling on persons sitting around the fire, the supply of fresh air for the room is conveniently admitted chiefly by a channel, *k l*, under the floor, leading directly from the external atmosphere towards the hearth, and there allowing the air to spread from about the fender. The fender, being exposed to the fire near it, becomes hot; the cold, fresh air then rising and touching it, takes from it the excess of its heat, and so becomes itself tempered before it spreads in the room. The two evils of excess of heat in the fender, and excess of cold in the air, thus meet to neutralise each other, and to produce a result which is good.

Now as to ventilation. The great importance of general ventilation is strikingly exhibited by such occurrences as the following, which happened not long ago in Glasgow. A large old building, which had been formerly a cotton mill, was fitted up as a barrack or dwelling-house for persons of the working-classes, and held nearly five hundred inmates. As occurs in all foul and crowded human dwellings, fevers and kindred diseases soon became prevalent there. After a time a medical man who was interested in the establishment obtained permission from the proprietors of a neighbouring chemical manufactory, in which there was a lofty and very powerful chimney, to make an opening of one foot in diameter into the side of the chimney for the ventilation of the lodging-house. He then connected with this opening a main tube from the lodging-house, of which branches led along all the passages or galleries, and into these, from the ceiling of every separate room there was a free way. Soon after, to the surprise as well as to the delight of all concerned, serious diseases entirely disappeared from the house, and were never reproduced

Now the chimney of the new fire-place, even when not very tall, has a ventilating power scarcely inferior to that of the Glasgow chemical works. The arrangement of the narrowed space over the fire with its valve, as above described, by allowing only unmixed and therefore very hot smoke to enter the chimney, instead of, as in common chimneys, smoke diluted with many times its volume of the colder air of the room, increases the draught just as it does the heat of the chimney, and through an opening then made into the chimney from near the top of a room, the hot, foulest air in the room, consisting, perhaps, of the breath of inmates, smell of meals, burnt air from candles, lamps, &c., and which else soon accumulates and stagnates near the top of the room, is immediately forced into the chimney and away. This is rendered strikingly apparent by placing near the ventilating opening a light body, as feathers or shreds of paper suspended to a thread, and seeing with what force it is drawn into the opening. In the diagram the opening is represented at the letter *v*, having the common balanced chimney-valve in it, which, by the wire descending to a screw within reach of the hand at *x*, can be shut or left free to open to any desired degree.

That valve was devised by the writer of this many years ago, and it is now extensively used over the country; but, in many cases, what was described as an essential concomitant—namely, the contraction of the chimney-throat and of the space over the fire—has been omitted, and the proper action of the valve has consequently been prevented.

From what has been said respecting the third of the great evils of the common fire, that also appears to be as remediable as the other two. Under the three heads the attempt has been made to explain how an open fire-place, scarcely differing in appearance from an ordinary English fire-place with its pleasing associations, may be constructed, which shall be smokeless, saving of much fuel, and insuring the healthful warmth and ventilation of our houses.

There are yet subordinate advantages in the new arrangement of fire-place, among which the following may be noted:—

1. Chimney-sweeping can be little wanted where there is no soot.

2. Chimney-flues without soot cannot catch fire, and, if fire were in any way there introduced, by shutting the throat-valve, it would be certainly extinguished. Thus a large proportion of the conflagrations of buildings may be avoided.

3. The huge evil (almost universal) of smoky or imperfectly-acting chimneys cannot occur with this grate.

4. The occasional sudden rush of air towards a hot wide chimney, produced when the room-door is opened, and which carries readily the light muslin dress of a lady towards the grate and sets fire to it, cannot happen with this grate.

5. The danger of sparks thrown on the carpet from

exploding pieces of coal does not exist here, for all the coal is gradually heated and coked while yet in the coal-box, and covered over. Thus a fire-guard is scarcely wanted.

6. The strong draught of a voracious chimney with wide throat, in one room, or in the kitchen of a house, cannot disturb and overcome the action of other chimneys in that house, as is now very common.

7. The strong draught of a well-constructed fire-place may, by a connecting tube entering anywhere above the damper-valve, be made to ventilate any distant room, staircase, cellar, closet, &c.

8. The strong and wide stream of draught in the chimney of this grate caused by momentarily opening the hood-valve or damper will prevent any diffusion of dust when the fire is stirred or disturbed.

9. The chimney-valve, by its powerful ventilating effect, obviates all objections to the use of gas-lights in houses; thus leaving the beauty, cleanliness, cheapness, and many conveniences of gas unbalanced by countervailing evil. Explosion from accidental escape of gas in a room or house, of which occurrence there have been some remarkable instances, cannot happen where there is the ventilating chimney-valve, for cold coal-gas entering a chimney-flue produces a more powerful draught than any ordinary smoke or hot air does.

10. The improved chimney draught in the necessarily short chimneys of attic or upper rooms will make these more valuable, and will also increase the comfort of low houses and cottages.

11. It will, in certain cases, be convenient to carry

the flue of a close stove, or bath, or the ventilating tube from lamps in staircases into some acting chimney.

12. This torch-fire (as some have called it, because it burns from above downwards, like a torch or candle) is well adapted also to all the purposes of the kitchen.

13. The change of any existing grate of an old fashion into this smokeless grate will, when the tradesmen have had experience, be easy and inexpensive. The so-changed grate, however, as is true also of any original form of the smokeless grate, may still be used as a common grate by any one who might wish so to use it. The fresh coal would have then to be thrown on the top of the fire as in a common grate, and the moveable bottom of the new grate would have to be fixed in its highest position level with the lowest grate bar. The chief differences then remaining between the action of the two would be the greatly improved draught of the chimney of the new grate, and the greater command possessed over the rate of combustion.

14. When, with the common grate it is desired to make a very cheerful blazing fire, as on the occasion of friends assembling in a cold evening, the end is obtained either by breaking up with the poker the mass of coal which has lain for some time smoking on the top of the fire, and has become heated and caked, or by placing billets of dry wood on the top of the fire. With the new smokeless grate the same object is obtained more quickly and permanently, by laying a solid lump or two of coal on the top of the fire. The intense heat of the upper surface of this fire almost immediately brings gas from the

bottom of the coal lumps to be at once converted into flame, of the purest kind, with little or no smoke. A succession of such lumps placed on the fire at long intervals keeps the flame steady for the whole day.

15. Any kind of coal or coke may be used in the smokeless grate, even the small culm or coal-dust, which is very cheap. In a common grate, coke or Welsh stone coal would be objectionable, because they give out chiefly heavy carbonic acid instead of the light steam and carburetted hydrogen smoke of bituminous coal, and the heavy gas, which is poisonous, might spread in the room. The strong draught of the smokeless chimney, however, suffices to carry away any kind of gas.

16. An important economy connected with the new grate springs from the fact of the chimney flue being nearly closed during the night. The wide heated flue of a common grate left open all night acts as a strong pump bringing cold air into the room at every crevice in the floor and about doors and windows, which air, after absorbing the heat from the furniture and walls, passes up the chimney, and before morning may have reduced the temperature of the room, and of all it contains, nearly to that of the external atmosphere. The action of a strong morning fire for hours is then required to restore the warmth which in the night was lost. The new grate having at all times a narrow chimney-throat, and during the night when there is no fire and no need for ventilation, having the chimney damper and the ventilating valve nearly closed, keeps the room nearly as warm until the morning as it was the evening before, and thus much coal and much

time are saved, and the comfort and health of the inhabitants are better secured.

The list of the subordinate advantages of the new grate might be extended, but those already noted will suffice.

It may be remarked here, with respect to the smokeless grate, as has been remarked with respect to many other simple applications of scientific principles to the arts of life, that the first adoption of the novelty has been delayed because popular misconceptions, founded on imperfect knowledge of nature's laws, had led persons to anticipate grave impediments in particulars which really involved important advantages. When the contrivance of the Water-bed or floating mattress was brought into use some years ago by the writer of this, which certainly prevents, and even in advanced cases effects the cure of the bed-sores from unequal pressure, which so often terminate in great pain the lives of patients long confined to bed, various persons had seen the possibility of constructing it, but never made the trial, from the fear that the coldness of the water might be a source of danger, and might render necessary some delicate and difficult means of regulation—the fact being, however, that because water is an absolute non-conductor of heat from above downwards, the water-bed becomes so warm, that small tubes of spiral wire have to be placed in the mattress to insure cool ventilation. So, in regard to the smokeless grate, of which the box underneath filled with coal allows no air whatever to ascend from below to support the combustion—as air ascends in a common grate through the bottom bars—persons generally have concluded, and the conclusion was strengthened by knowledge of the faulty performance of one grate of the kind extensively tried about thirty years ago—that such a grate could produce only a fire likely to be

1, dull or flameless, and little under control.

2, very troublesome to servants.

3, difficult to be lighted, and extinguished.

4, smothered by its own ashes lying on the top, and sending much dust into the room.

5, requiring a chimney with unusually good draught.

6, requiring the use of coal of a particular kind.

Now the real qualities of the new grate are nearly the reverse of all these, besides its having the three primary characteristics above described at length.

FARTHER EXPLANATION OF THE DIAGRAM.

It is first to be observed that the smokeless grate may be made of any desired form, from that of the most graceful drawing-room grate, to that of the kitchen range; and that almost any existing grate may with little change of appearance be converted into a smokeless grate.

In Fig. 1 the letters *e f g h* mark the box or receptacle of cast iron, about nine inches deep, to contain the charge of coal for the day. It may stand on feet on the hearth, or may be fixed to the grate. A narrow space of about a quarter of an inch is left between the lip of the box and the surrounding bricks of the fire-place, to allow some air to rise to quicken the combustion. Besides its bottom, *g h*, the box has also a moveable plate *s s*, like a piston with its rod, on which the coal immediately rests, to be raised or let down as wanted. The piston-rod having passed through the bottom of the box is steadied by a guide-hole in a fixed stirrup or other bar, *i j*, or in the hearth-plate below. The piston-rod has notches or openings in it to receive the point of the poker, which, acting as a lever, with its fulcrum in any convenient fixed part, lifts the piston. A catch, *i u*, falls into the notches, or a pin enters the holes as the piston rises, to maintain it in its place.

In the centre of the bottom is the small door, to allow the removal, before lighting the fire in the morning, of the broken coal or ashes which may have fallen past the piston. Where the coal-box is deep, or the grate is set low, an opening is made in the hearth to allow the end of the piston to descend.

The letters *a b y* show a hood or cover of metal like an inverted funnel opened in front, placed over the fire to contract the free space usually left above the grate, and to receive the true smoke of the fire, and convey it little diluted into the chimney-flue at *y*. In general this contraction of the space is best obtained by the arrangement of the fire-bricks which form its sides and back. In the front of the space there is a sliding door or blower by which is regulated the quantity of air admitted to mix and burn with the gases rising from the fuel.

The letter *t* marks the throttle-valve, or other damper, placed in the narrow part of the chimney-throat to give complete control over the current of air passing through. This has a hand or index externally, showing clearly at all times the position of the valve.

The letters *y v* mark the direction of the chimney-flue in the wall, generally bending to one side to avoid the fire-place of the room immediately above.

The letter *v* shows the ventilating chimney-valve, admitting air from near the top of the room to the flue. It is balanced nearly on its centre of gravity, so that the least pressure from without opens it inwards, but any pressure from within, as of smoke, closes it. There is a wire descending from the valve, to a screw or loop-peg at *x*, for partially or wholly closing it.

There is a channel underneath the hearth indicated by the letters *k l*, by which fresh air, directly from the atmosphere, enters the room, to be warmed under the fender or about the fire, and then to be diffused in the room. It also has a controlling-valve.

To show how easily a common grate can be converted into a smokeless grate, of moderately good construction, an ordinary bed-room grate was taken for a first experiment. The bottom bars on which the fire had rested were removed. The space beneath, towards the hearth, having fire-bricks at the back and sides, was converted into a box-like receptacle for coal, by an iron plate placed like a door in front of it, and a moveable bottom formed like a piston, to support and raise the coal, was shaped to fit that receptacle. This construction is cheaper than where the separate box is used, but it wants several important advantages of the box, particularly in regard to control over the combustion, and the facility of replenishing with fresh coal when desired during the day. The author has continued the specimen here described in action for two winters, with much advantage, but he does not recommend such form for ordinary use.

Another modification of the smokeless fire can be made which has the column or mass of its coal placed immoveably in the grate or receptacle, in front of which are fire-bars that can be lowered as the coal is consumed, so as to admit to lower portions of the coal in succession the required supply of air. But this arrangement soon becomes a *low* fire, with all the disadvantages described in the section which follows this, besides various others. It was one of many forms considered and rejected by the writer when he decided to recommend the construction of the coal-box and piston above described.

A very simple form of a nearly smokeless fire can be made on a raised hearth of fire-brick or stone, in which a sufficient cavity or depression exists to receive the fresh coal, which cavity can be refilled from time to time by raising or displacing the burning fuel with a fit spade or shovel, while fresh coal is being thrown in beneath. It is possible even in a common grate to raise the burning fuel by a large flat shovel, so as to allow the introduction of fresh coal underneath.

THE ERROR OF PLACING FIRE-GRATES LOW.

A fashion has lately been introduced into this country of placing the fire-grates much lower down than formerly—in some cases, on the very hearth—the reasons usually assigned being that a low fire burns better, or gives out more heat from the same quantity of fuel, than a higher; and that because lower and nearer the floor, it must warm the carpet better, and so prevent or lessen to the inhabitants the evil of cold feet. Now, both these suppositions are curious errors or delusions, having their origin in popular misconceptions respecting the nature and laws of heat, and particularly respecting the law of radiation.

Radius is the Latin word for the spoke of a wheel, and anything which diverges or spreads around from a centre, in some degree like spokes, is said to radiate. Light and heat are of this nature. The portion of either which passes in a straight line from the source is called a ray.

Simple observation teaches all persons that a lamp placed in the middle of a room radiates its light nearly equally in all directions; and most persons are aware also that a lamp, or a fire, or a mass of red-hot iron radiates heat as well as light in all directions; but because in placing a hand directly over any of these more heat is felt than when the hand is at a side or below, they are disposed to conclude that the radiation of heat is much greater upwards than laterally or downwards. This conclusion, however, is erroneous, and the explanation is, that above the fire there is not only the heat of radiation, but also the heat given to the air which has fed the combustion and to the air which has touched the heated grate, or other mass below, which air being dilated by the heat and rendered specifically lighter is forced directly upwards.

Most persons are aware that if a good mirror be placed close to a lamp on one side, it not only intercepts all the rays that fall upon it—which means nearly half of the light given out—but that it returns or reflects these rays back in contrary corresponding directions, and nearly doubles the illumination in those directions; but many do not learn, by their unaided observation, that if a surface of any substance, like fire-brick, which strongly resists the passage of heat through it, be placed near a fire, it not only intercepts the heat-rays falling on it, but by absorbing them, and so becoming heated, often to redness, it then reflects and radiates back the greater part of the heat, almost as if it were additional hot fuel in the fire, and thereby nearly doubles the warmth felt in directions away from the surface.

It has been ascertained that of the heat produced by combustion in a common fire, one part—being somewhat more than half—is diffused, like the light, by radiation, into the open space around, and that the remainder is given, by contact and conduction, to the air which supports the combustion, and to the solid material about the fire-place. Thus, then, with a common open fire-place, it is the radiated heat almost alone which warms the room, while the remainder either at once combines with the burned air or smoke, and passes up the chimney, or being given by the heated grate to pure air which touches that, passes into the chimney with the smoke.

And lastly, many persons do not suspect the truth, that the rays of heat passing through pure or transparent air do not at all warm that air, but warm only the solid or opaque bodies by which the rays are intercepted, and that thus the air of a room is warmed only at second-hand, by contact with the solid walls and furniture which, having intercepted the heat rays, have themselves first become heated. Yet most educated persons know similar facts, such as that the sunbeams, bringing to the earth both its light and heat, as they descend to warm the hottest valleys or plains, pass through the upper strata of the atmosphere, but leave them always of a temperature much below freezing. This low temperature is proved by the fact that all lofty mountains, even under the equator, are capped with never-melting snows, and that the higher the peaks are, though, therefore, the nearer to the sun, the colder they are. Thus, also, all persons who have attended to the subject know that aeronauts, in their balloon-car, if they mount very high would be frozen to death if not protected by very warm clothing. Another fact of the same kind is, that a glass globe, full of cold water, or even a ball of ice, will in the sun's rays act as a burning-lens.

These explanations being premised, the two popular delusions respecting low fires become at once apparent.

1st. The supposition that fuel burnt in a low fire gives out more heat, has arisen from the experimenter not reflecting that his hand held high before the low fire feels not only the heat radiated from the fire itself, but also that reflected from the very hot hearth, close beneath it, which second portion, if the grate were high, would have freedom to spread or radiate downwards and outwards to the more distant floor or carpet, and to warm them.

2nd. The notion that the fire, because nearer to the floor, must warm the carpet more, springs from what may be called an error in the logic of the reasoner, who is assuming that the hearth, floor, and carpet, being parts of the same level, are, as regards the fire, nearly in the same predicament—the truth being, however, that in such a case the hearth within the fender gets nearly all the downward rays, and the carpet almost none—somewhat as in the case of a candle held before a looking-glass, which, at a moderate distance diffuses its heat pretty uniformly over the whole, but if moved close to one part of the glass it overheats, and probably cracks that part leaving the rest unaffected. A low fire on a heated hearth is to the general floor or carpet of a room nearly what the sun, at the moment of rising or setting, is to the surface of a level field. The rays from the fire are nearly all shooting upwards from the surface, and the few which approach it slant very obliquely along, or nearly parallel to, the surface, scarcely touching, and therefore not sensibly warming it. The use, lately become common, of radiating surfaces of polished steel placed over the hearth cannot increase the heat, but simply bends upwards some of the rays which would else fall on the rug and carpet, warming them.

The annexed diagram serves to elucidate these facts.

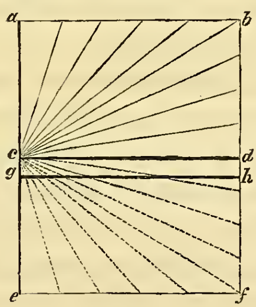


Fig. 2.

c represents a fire-place or centre of radiation, with rays diverging from it into all free space around.

a c the wall in which the grate is set, and which evidently can receive none of the direct rays,—as is nearly true also of the floor, *c d*, if the fire be on the hearth.

a b the ceiling.

b d the wall opposite to the fire.

c d the floor, with the fire on or close to the hearth. If there were no floor at all there, rays (here indicated by dotted lines) would shoot as abundantly down to the bottom and walls of the room below, *c*, *d*, *e*, *f*, as to the ceiling and walls of the room above; but the hearth-stone of the floor, *c d*, first intercepts all the descending rays (half of the whole) and then radiates them up to the ceiling and upper walls, leaving the floor unsupplied unless by secondary radiation from the ceiling and walls.

g h represents a floor at a moderate distance below the fire. In such arrangement it is seen, by where the ray-lines intersect this floor, that much of the heat of the fire must spread over it, and chiefly between the middle of the room and the grate, where the rug is, and where the feet of the persons forming the fire-side circle are placed.

Striking proof of the facts here set forth is obtained by laying thermometers on the floors of rooms with low fires, and of similar rooms with fires, as usual of old, at a height of about fifteen or sixteen inches above the hearths. The temperature in the upper parts of all these being the same, the carpets in the rooms with low fires are colder by several degrees than those in the others.

As would be anticipated by a person understanding the subject aright, low fires occasion coldness of the feet to inmates, unless when they sit near the fire with their feet on the fender; but many of these, deceived by their fallacious reasoning, are disposed to blame the state of their health or the weather as the cause, and they rejoice at having the low fire, which can quickly warm their feet when placed near it. A company of such persons seen sitting close around their fire with thankfulness for its warmth near their feet, might suggest the case of a party of good-natured people duped out of their property by a swindler, and afterwards gratefully accepting a portion of it from him as a charitable contribution.

Many persons have been prevented from detecting the truths connected with low fires by the fact, that where the chimney-breast or opening is also made low, the mass or stratum of comparatively stagnant warm air detained in the room is deeper or extends lower than where the chimney-opening is high, and the room thus arranged may be in the upper part somewhat warmer than before, although in the lower part colder. But any partial advantage from this arrangement is often missed by the chimney-throat being left too wide, causing strong cold draughts through the room; and where there are many persons in the room, the possible good is more than counter-balanced by the ventilation above being rendered in proportion more faulty. In the new smokeless grate, there is the advantage of a low chimney-opening combined with a high fire, and the ventilation at the same time is maintained perfect for any amount of crowd by the ventilating valve placed near the ceiling of the room.

PART SECOND.

THE VENTILATION OF ORDINARY DWELLINGS.

Farther scientific details will be given afterwards respecting the nature of life, and the constant dependence of life on breathing, and respecting the conversion by breathing of the pure air which sustains, into foul air which poisons. But it is befitting here to begin by observing that atmospheric air, although very much lighter than water, is as truly a material fluid as water; obeying the same laws of motion and pressure, and containing, indeed, one of the same ponderable elements—namely, oxygen; that it covers the surface of the earth as an ocean about fifty miles deep, in which men live and breathe by their lungs as fishes live and breathe by their gills in the sea; that on the surface of the earth every space unoccupied by other things is filled with air driven in by the strong pressure of the deep mass above; as at the bottom of the sea every open space is filled with water under the similar pressure of the watery mass above; and that, as there are currents, and tides, and floods in the sea, so there are winds, and draughts, and storms in the atmosphere. Because, however, air is so light and transparent, and so little resists things moving in it, that human touch or sight scarcely perceives it, men until a comparatively recent time did not suspect it to be a ponderable substance at all; and still a child or uneducated person anywhere, looking into what is called an empty room, believes it to be absolutely empty. Many of the effects, therefore, of the pressure and movements of the ocean of air lying on the face of the earth, although now so intelligible and completely under control to instructed persons, appear to ordinary observers almost as mysterious and capricious as would be the motions of a boat impelled by invisible oars and rowers. Among such effects are the phenomena of the ascent and travelling of a balloon; the rising of water from a pond or well, to follow the piston of a common pump; the action of the syphon; of barometers; of cupping-glasses; and, lastly, the phenomena which particularly claim attention, here, the departure upwards from a living animal of the air, which has been defiled by respiration, and the very important action commonly called chimney-draught.

A man's chest contains nearly two hundred cubic inches of air, but in ordinary breathing he takes in at one time, and sends out again only about twenty cubic inches—the bulk of a full-sized orange—and he makes about fifteen inspirations in a minute. He vitiates, therefore, in a minute, about the sixth part of a cubic foot; but which, mixing as it escapes with many times as much of the air around, renders unfit for respiration three or four cubic feet. The removal of this impure air, and the supply in its stead of fresh air, is accomplished thus: the air which issues from the chest, being heated to near the temperature of the living body, viz, ninety-eight degrees, and being thereby dilated, is lighter bulk for bulk than the surrounding air at any ordinary temperature; and it therefore rises in the atmosphere to be diffused there as oil set free under water rises; in both cases a heavier fluid is, in fact, pushing up and taking the place of a lighter. This beautiful provision of nature, without trouble to the party or even his being aware of it, is relieving him at every instant from the presence of a deadly though invisible poison, and replacing it with pure vital sustenance; and the process continues while he sleeps as while he wakes, and is as perfect for the unconscious babe, and even the brute creature, as for the wisest philosopher. In aid of this process come the greater motions in the atmosphere, called winds, which mingle the whole, and favour agencies which maintain the general purity.

When, in the progress of civilization, men seeking shelter from rain, cold, and other disagreeable states of the atmosphere, construct houses or enclosed spaces, the ceilings of these obstruct the natural rising away of foul breath, and the walls prevent the beneficial action of the winds. Serious evils then arise, at first little suspected or understood, which can be avoided only by substitutes, called "means of artificial ventilation." Of these, the first to be considered here is the *Chimney Valve.*

THE VENTILATING VALVE.

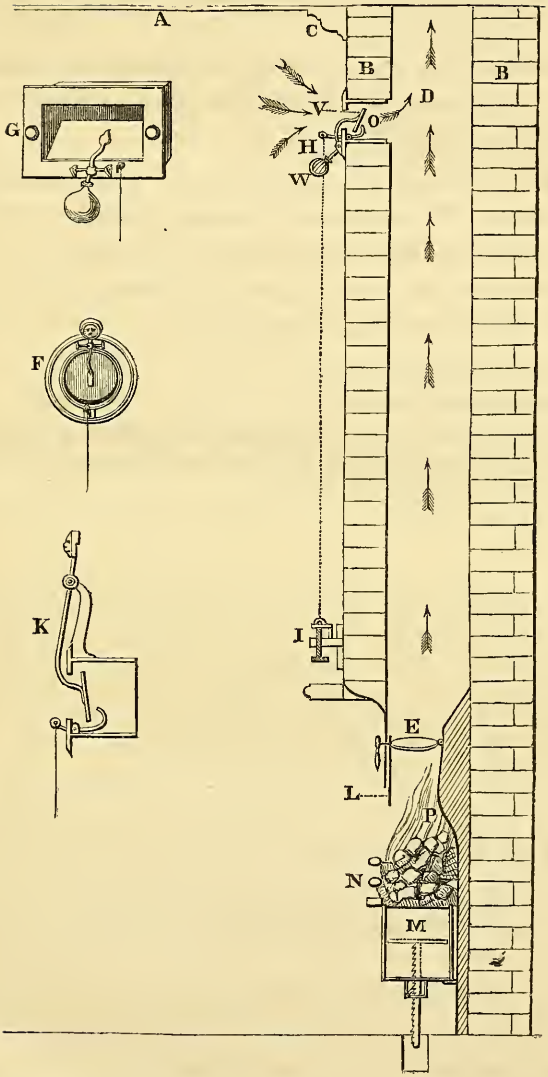
In sitting-rooms, bed-rooms, nurseries, and enclosed places generally, where people assemble, the impure air of the breath, the burned air from lights, the odour of dishes, &c., because heated and therefore specifically lighter than common air, all ascend first towards the ceiling; but, as in ordinary rooms, no opening exists there for escape (for an open window-top in a room which has an open fire-place only admits the cold air), they soon contaminate the whole air of the room down to the level of the chimney mouth, through which only can any portion ultimately pass away. In this way arises great, though often unsuspected injury to the health, and finally to the constitution of the inmates. The pale faces and scrofulous constitutions of the inhabitants of towns, and of others who live much within doors, are mainly effects of this evil. The ventilating valve is placed in an opening made from the room into the chimney-flue, near the ceiling, by which all the noxious air above referred to, is allowed at once, in obedience to the chimney draught, to pass away, but through which no air or smoke can return. The valve is a metallic flap to close the opening, balanced by a weight on an arm beyond the hinge. The weight may be screwed on its arm to such a distance from the axis, or centre of motion, that it shall exactly counterpoise the flap, but if a little further off it will just preponderate, and keep the flap, when not acted on by entering air, very softly in the closed position. Although the valve, therefore, be heavy and durable, a breath of air suffices to move it; which if from the room, opens it, and if from the chimney, closes it; and when no such force interferes, it shuts. The valve is so adjusted originally as to settle always in the closed position. An important part of the arrangement is the wire, which descends like a bell-wire from the valve to a screw or peg, fixed in the wall within reach of a person's hand, by acting on which the valve may be either entirely closed, or left free to open in any desired degree. In cold weather, or with few persons in the room, the valve, when opened only a little, allows as much air to pass as is requisite. A flap of thirty-six square inches area is large enough where there is good chimney-draught, for a full-sized sitting-room with company.

It is to be observed that if the opening or throat of the chimney-flue over the fire be so wide that more air can easily enter there than can escape at the chimney-pot above, the chimney will not take air in also at the ventilating valve. It is essential, therefore, that with ordinary grates the register flap be so far closed, that when the fire is lighted, little more than the true smoke shall be allowed to enter; and not also, as is usual, much of the pure air of the room escaping with it to waste. A second great fault in common fire-places is the large space left between the fire and the chimney-throat, in rising through which the true smoke contaminates much good air, which must then be allowed to pass away as smoky air. Both of these errors are completely corrected in the smokeless grate described in the last chapter.

Fig. 3 exhibits, in section, a ventilating valve in its place.

A C, is part of the ceiling of the room.
C, the cornice.
D E, the chimney-flue in a brick wall.
O, the opening in the wall in which the valve-case is fixed.
V, the flap or plate of metal.
H, the hinge like that of a weigh-beam on which the flap turns without friction.

Fig. 3.



W, the counterbalancing weight.

H I, the wire by which a hand below at the screw or peg I, controls or shuts the valve. The wire pulls at the short arm of a bent lever of which the long arm then presses on the back of the plate to close it.

G, is a front view of a valve. It may be made of a square form as here shown, or round, and it may have its hinge above or below the opening.

F, a round valve with the hinge above.

K, a valve suspended like a pendulum from a point considerably above. The same proportions may be adopted with a hinge below, but requiring then a heavy counterpoise.

The lower part of the drawing gives a side view in section of the smokeless grate:—

M, the coal-box with its piston.

N, the grate with fire in it.

P, the fire-brick of the back of the fire-place, inclining forward from the level of the upper bar to narrow the space over the fire.

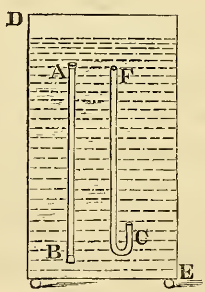
L, the sliding blower-plate in front.

E, the chimney throttle-valve. Other forms of damper may be used.

The ventilating valves have been manufactured well by Messrs. Bailey, of 272 Holborn, and by Mr. Edwards of 42 Poland Street. Many other makers, from the idea that the appearance would be more pleasing if the hinge and counterpoise were not in sight, placed them internally, or behind the face, instead of externally as directed, thus increasing much the difficulty of correctly balancing the valve-plate and of keeping the hinge clean. Disappointment has been occasioned in thousands of instances from this error.

Chimney-draught.—The popular notions respecting chimney-draught are still as curiously erroneous or contrary to the truth as were those respecting sunrise and sunset, when men believed that the earth was immoveable, and that the sun was always travelling round it once in twenty-four hours. They are, that heat and therefore heated air have a natural tendency to rise just as a stone has a tendency to fall, and that a chimney-flue exerts a mysterious power which increases that tendency so as to draw more air into the room by windows, doors, or any open chink, to supply the place of what is passing away. Now to think thus is as absurd as it would be to think that there is a natural tendency upwards in a block of wood, because when plunged into water it rises to the surface; or, in a lump of iron, because that similarly rises and swims in a trough of quicksilver; or in a bladder filled with oil, because that, if placed in water rises to the surface; or, lastly, in a quantity of hot water, because that, if placed in a bladder or bag, and immersed in cold water, rises to the surface like the oil. Most persons know that in all such cases the substance which floats retains its natural weight or tendency downwards as much as ever; but that being lighter, bulk for bulk, than the fluid around it —that is to say, specifically lighter—it is pressed or buoyed up by that fluid as certainly as any weight hanging at the end of a weigh-beam is pressed up by a heavier weight hanging at the other end. And in regard to the hot water particularly, they know that the heat in it does not make it in the slightest degree less heavy than if weighed by itself; but that by rendering it more bulky, as increase of temperature renders most substances, it changes the floating relations of the masses, and so indirectly causes the hot water to be buoyed upwards in the colder water. In a few remarkable cases, cold, or abstraction of heat, causes substances not to contract but to dilate—and curiously, this happens in regard to water itself when near its freezing temperature—and then the increase of cold causes the dilated substance to float upwards. Thus very cold water floats on the surface of a mass of cool water just as very hot water does, and water converted into ice is so much more bulky or specifically light that it floats with a considerable part of its volume above the liquid surface. These hydrostatic facts are fully explained in books on Physics or Natural Philosophy, under such statements as the following:—"Any body immersed in a fluid displaces exactly its own bulk of the fluid, which quantity having been just supported by the mass around, the body is buoyed up with force exactly equal to the weight of the fluid displaced, and must sink or swim, as its own weight is greater or less than this." Now air being a material fluid, as truly as water, of small but certain known weight and pressure, the rising of heated air in a colder atmosphere, as when the *hot-air balloon* mounts upwards, or when hot smoke ascends either in the open air or in a chimney-flue, exposed to atmospheric pressure—is a phenomenon of the very same nature as those above referred to.

Fig. 4.



If a tube A, B, filled with oil, and closed by corks at both ends, be immersed upright in a vessel of water, D, E, and if then the lower cork be removed, the oil will not fall out or sink into the water below, but will, as a specifically lighter substance, be supported, and made to press upward on the cork A. If the upper cork also be then removed, the heavier water around will force out all the oil towards the upper part of the vessel by an equal bulk of water entering below. The force driving the oil upwards in such a case, is exactly the difference between the weight of the oil and of an equal column of the water, which would have been supported there, if there had been no oil. Now this experiment indicates correctly what happens in a chimney-flue, containing the smoke of a fire below, or in any channel which contains heated air, and which has communication above and below with the atmosphere. What is incorrectly called the chimney-draught is a force exactly equal to the difference of weight between the dilated air in the flue and an equal column of the external atmosphere. This explanation shows why chimney-draught is directly proportioned first, to the dilatation, and therefore to the heat of the air in the flue, and then also to the length or height of the chimney, and it accounts for many of the common cases of smoky chimneys, and suggests appropriate remedies. An influence often overlooked, but of considerable importance, because it continues in operation during the summer, when there is no fire, is the exhausting action produced by wind blowing directly across the end of an open tube, such as a chimney-pot. The stream of air splitting on the chimney-pot, causes a degree of vacuum at the mouth, towards which the air from below moves. The new arrangement of the smokeless grate, described in the first chapter of this work, by increasing manifold the force of chimney influence, will diminish hereafter the value of numerous old expedients.

If to the bottom of a tube as A, B, in the last figure, a bent piece be added, as at C, giving the form of an inverted syphon, the so-called *draught-action* of the tube, whether of glass filled with oil, or a brick-flue filled with hot smoke, or a ventilating tube of any material, filled with hot breath or other impure air, would be weakened in exact proportion to the length of the short leg C, because force has to be expended to compel a lighter fluid to descend, where surrounded and acted on by a heavier. This explains the case of what is called "a fire with a descending flue," the difficulty of causing which to act satisfactorily is well known. To manage aright a descending flue, for whatever purpose used, is proof of a certain degree of skill in pneumatics, but a man who, without such knowledge, meddles with the arrangement, is almost sure to exhibit his deficiency. A strange instance of this kind took place two or three years ago in the case of a patent taken out by a Doctor for a so-called "inverted syphon ventilator." The deluded patentee believed he had discovered a new principle in nature, namely, that a bent tube had a power, by virtue of the bend itself, of giving motion to the air contained within it. Singularly, however, he missed seeing that if this were true he had solved the problem of the *perpetual motion*. It would seem that from the omission, too common formerly, in the prescribed courses of professional education, of sufficient study of the principles of physical and mechanical science, he had not well understood chimney-draught, whether as depending on heat, or syphon action, or atmospheric pressures, or the effect of wind blowing across the end of an open tube, and so concluded that the bend in the tube, which was in fact an obstruction, was the prime cause of the current. The absurdity was really as great as if a man were to hang a weight to a waggon ascending a steep road and were to attribute the motion of the waggon to the influence of that weight and not to the pulling of the horses. The bend had long been used in chimneys with descending flues, and in ventilating flues and pipes, where foul air had to be taken from a higher level than some part of the outgoing channel, but the weakening of the draught produced by the bend was perfectly known and allowed for.

In many cases where the ventilating valves have been introduced in connexion with chimneys originally well constructed, or with any chimney of which the parts near the fire were narrowed purposely to suit the valve, the good effects obvious to any apprehension have as much surprised as they have pleased persons to whom the subject was new. The following instances are selected, to give an idea of these effects. Each may be considered to represent a numerous class of similar cases which have fallen under the immediate cognisance of the writer, or of trustworthy witnesses who have reported to him.

1. In London there are localities occupied by the poorest classes of the labouring population, in which a single room is often serving as the dwelling of several

families. A poor widow will hire a room, and placing her own table and bed in the middle, will gain her bread by subletting every corner to a separate family. The crowding and filth in such places cannot be truly imagined, but by persons who have themselves made an inspection. From one of these localities, in St. James's parish, as described in a future part of this volume, sick persons were always crowding to the neighbouring dispensary, or requiring attendance at home. The senior surgeon, Mr. Toynbee, deeming the vitiated atmosphere of the rooms a principal cause of the evil, consulted the writer of this work on the case, and at his suggestion had small openings made into the chimney-flues, near the ceilings of the rooms. This change was quickly followed by a remarkable diminution both of the number of patients and of the severity of the diseases,—as reported by Mr .Toynbee in evidence given before the Health of Towns Commission in 1846.

2. A lady in Bedford-square, after her return from the country where she had been staying during the progress of repairs in her house, became so subject to violent headaches and irregular neuralgic pains, that she was often obliged, early in the evening, to withdraw to her bedroom. Her medical attendant at first saw her only in her bedroom, and could discover no sufficient cause for her illness; but after a time, he learned that gas-lamps had been placed in the dining-room, with no other ventilation but by the low open fire. He advised the adoption of the high ventilating valve, and after the change made the headache never returned. Such cases have been numerous and striking, particularly where rooms were

small and the ceilings low, and the number of inmates considerable.

3. It is a well-known fact, that in shops strongly lighted by gas lamps, the shopmen when they mount to take things from high shelves, are often distressed by having to breathe the burned air accumulated above. Relief to a great extent is obtained by placing ventilating valves in the chimneys, and the relief is complete if inverted funnels be fixed over the gas flames, with tubes leading from them to the valves. If the valve openings be made at a considerable distance below the ceiling, persons can breathe freely below the level of the valves, but not above.

4. The wretched sleeping-rooms resorted to by mendicants and other vagrants in great towns, have their inmates often lying on the very floors, and so thickly crowded as completely to cover the floors. Yet it has been remarked that in these houses disease was less frequent and destructive than in some others which were not so crowded, and where there were raised benches or bedsteads for the sleepers. The explanation is, that in the first-mentioned rooms the heads of the sleepers were considerably below the level of the chimney openings, or fire-places, and had therefore more free ventilation than the others.

5. Two ladies of a family which had suffered misfortune, sought to support themselves by opening a day-school near their former home. The schoolroom on the ground floor, with a common fire, contained in a short time a considerable number of pupils, but in a short time too the health of both the mistresses was seen to decline, and particularly of the younger, who sat more constantly among the scholars: she became

very weak, and subject to headache and to hysterical affections. Some of the children also were occasionally indisposed without a cause which their parents could assign. After a time the room was ventilated by a chimney-valve, and all the evils ceased.

6. A numerous family from a large house and garden in the country, came to reside in London. After an interval, a former neighbour and old friend, paying them a visit, could not refrain from telling the mother that she thought the bloom of health, formerly so remarkable in the daughters, had notably faded, and she attributed the change to the town air. About that time one of the children had an accidental illness, which required professional attendance, and the medical man, observing the crowded bedrooms imperfectly ventilated, and therefore little fitted to constitutions accustomed to pure country air and much out-of-door exercise, advised that valves should be introduced. All the members of the family were sensible of a pleasing change. The friend whose remark had created alarm, at a second visit made some time after, not aware of what had been done, gladly observed that the fresh looks of the young people had in a great degree returned, and she concluded that their systems must have accommodated themselves to the town climate.

7. Ventilating valves, as a sanitary precaution, were placed in a house inhabited by a numerous family. A friend calling sometime after, remarked that the very fresh looks of the children, whom she had met on the stair, would have made her conclude that they were just returned from their annual sea-side holiday, instead of being about, as they were, to depart for it.

8. In a family living in a good house, near Russell-

square, one of the children aged four years, was observed to have a gland of the neck beginning to swell, and the mother was much pained by hearing that some person had called the affection scrofulous. She was not yet aware that the foul air of a crowded dwelling is all-sufficient to produce scrofula, as well as many other diseases.* The medical friend consulted on the occasion had at former times remarked favourably on the healthfulness of the children and the management of the mother. Now, however, within a short time, twin children had been added to the family, with another servant, and low grates had been substituted in the sleeping rooms, for the old-fashioned grates with high mantel-pieces which favoured ventilation by allowing escape for hot air from above the level of the children's beds. All the children, therefore, during the night were now breathing the impure air which accumulates in the upper part of unventilated bed-rooms. On examining the whole family, it was found that the general health, not only of the little patient with the swollen gland, but of the others also, had of late become notably impaired. There could be no doubt that the new state of the atmosphere in the house was the cause of the evils. Ventilating valves were introduced. Not more than a month afterwards the medical adviser was called again, but then only to witness the happy effect of the simple remedy prescribed—for to the new ventilation the mother was attributing all the good obtained. A single fact, however, remained unexplained. The nurse who had entered the family

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* See the case of the Pauper-school at Norwood, related in page 87.

long before had for more than a year become so weak, and liable to what she called a constant weight on her head, that she was incapable of much active exertion, and was retained in her post chiefly for her trustworthiness and experience. She also now had regained health and activity, but as she had been ill for more than a year, while the children remained well, and she was supposed to have been breathing the same atmosphere as the children, it was concluded that the cause of her illness could not be the same as that of theirs. The truth was, however, that the nurse had not always breathed the same atmosphere, for being taller than the children, and constantly in the nurseries, with her head in the comparatively stagnant air above the level of the chimneys, while the children until the lowering of the grates, were always in comparatively pure air below that level, she had breathed the impure air much longer than they. The high ventilating valve cleared away the pernicious air from both nurse and children.

9. Another family of ten children, residing in the same quarter of the town, attracted the attention of the writer soon after the last-mentioned case, as affording further evidence of a similar kind. In that family, too, there was a valued old nurse, who for a long time, during the mornings, which she passed in the upper part of the house, among the unventilated bed-rooms and nurseries, had been very unwell; and there were the little children whose heads were yet below the level of the mantel-pieces, and who, therefore, had good health; and there were the older girls, whose heads were in the less pure air above that level, who were pale and had palpitations and hysterical affections.

The introduction of the ventilating-valves singularly lessened all the evils.

10. A family with four young children, for the sake of purer air, removed from a good house in St. Helen's Place, Bishopsgate, to a still larger house and extensive garden, beyond Camberwell. The children throve remarkably for a time, but then began to exhibit an unfavourable change. One became so ill that he was put under professional care. He was pale, thin, downcast, and had lost his appetite: while examining into his case, the attendant found that all the other children were similarly unwell, in a lighter degree; and he further found that the head nurse, for the sake of having all the children more under her eye, had some time before removed them from three ordinary bedrooms with fire-places into one large room on the upper floor, in which there was no fire-place, or other ventilating opening, and into which six beds were then placed. Return to the former bedrooms at once cured them all.

In the crowded hovel of an Irish or Scotch peasant, which has only a hole through the roof to allow the escape of the smoke, the air rarely becomes so oppressive as in more costly cottages elsewhere, which have brick walls, containing well-formed chimney-flues that rise from near the floors; and the blooming health of the flocks of little children issuing from such humble shelter has often surprised and excited the remarks of passing travellers. The explanation is, that in the ruder houses there are high openings for ventilation and in the others the openings are low.

These few instances exhibit the influence of pure and impure air, in ordinary dwellings. In the section

"On the nature of Epidemics," given below, are collected other instances, to exemplify what happens among crowds of human beings in schools, hospitals, ships, camps, &c.—(See page 81.)

The striking good effected by the ventilating valve in such cases as above selected soon caused it to be introduced to a considerable extent throughout the country; but so little was and still is the nature of what is called chimney-draught understood, not only by people in general, but even by stove-makers, builders, and architects, who have to apply the knowledge, that the two conditions pointed out as essential to the perfect action of the ventilating valve—namely, the narrowing of the chimney-throat by some kind of damper or register perfectly under command, and the diminution of the open space between the fire and the chimney-throat—have been much disregarded, and many ordinary fire-places being very faulty in both these respects, the objects sought have been in many cases very imperfectly obtained. And, thus—although the valve when fitly introduced can no more fail to do its work well than a stone can fail to sink down when left unsupported—the disappointments occasioned by faults in the setting have led many persons to think that the valve is of uncertain efficacy, and adapted only to a part of the cases where its agency is required.

Seeing the prevailing want of knowledge in regard both to the importance of ventilation and the means of accomplishing it, the author of this work—who had previously been consulted on various questions of public health by the Poor Law Commissioners, the General Board of Health, and other public authorities—deemed it his duty in 1849, when the cholera was in the country, and evidently much more destructive because of the imperfect knowledge referred to,—to make a formal report on the subject to the General Board of Health, and to suggest to the Board the formation of a committee of scientific men to examine the matter fully, and publish their conclusions. That report was written on the occasion of the General Board of Health having requested Professor Graham, now Master of the Mint, and the writer of this to consider conjointly and advise respecting the ventilation of the London Fever Hospital, which was then being rebuilt. The report contained the following paragraph :—

"As the decision of the Board of Health authorised by government to interfere in such a matter will affect not only this hospital, but for a time also may affect others, and as at the present moment of the prevalence in England of the destructive epidemic cholera, the whole question of the ventilation of dwellings has acquired a singular importance from the fact positively ascertained, that the spreading and severity of the epidemic depends more on the condition and circumstances of the persons exposed to it than on the mere presence of the peculiar morbific agent, and on no circumstance so much as on the purity or impurity of the air in houses and neighbourhoods—for these reasons the occasion seems to be now offered of doing a great public benefit, by obtaining decisions on the subject of ventilation from a committee of eminent scientific men, whose opinions, carrying public confidence with them, would have the authority of a law. I take the liberty, therefore, of recommending to the

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Board of Health to convoke such a committee, instead of requiring from Professor Graham and me the repetition of a report which has already been given with little effect. This committee would have to consider the three subjects of—purity of air—the means of moving air—and the influence of pure and impure air on health and life. It should unite, therefore, members specially skilled in chemistry, mechanics, and the science of health and disease, in other words chemists, engineers, and physicians. The physiologist or physician necessarily studies all the subjects, but should here meet other men of high special skill in chemistry and mechanics. To Professor Graham, President of the Chemical Society, who has lately been consulted, may be added Professor Faraday or Professor Brande as chemists; and, further, two or more engineers, and two or more physicians of like eminence. The decision of such a committee would settle several questions at present of much importance; and while the deadly pestilence is among us, surely nothing which promises mitigation of its ravages can be deemed to cost the public too much care or trouble."

August 1849.

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The Scientific Committee here recommended was not formed. The members of the General Board of Health of that day did not deem the subject of the importance which it had in the opinion of the writer of this. Could they have foreseen many events which have since occurred—the disastrous effects, for instance, of the foul atmosphere of the hospitals in the Crimea and neighbouring parts, on the sick and wounded of the British forces employed there,—their decision might have been different. They contented themselves with inserting in one of their manifestoes a short commendatory notice of the chimney-ventilation devised by the writer. That notice spoke so briefly of the nature of the arrangements for chimney-ventilation, that in answer to many inquiries addressed to him on the subject, the writer published the following letter in the 'Times' newspaper of the 25th September 1849.

THE BOARD OF HEALTH—VENTILATION.

To the Editor of the Times.

Sir,—In the notification from the Board of Health respecting cholera, reprinted from the *Gazette* in your paper of the 19th instant, the following passage occurs after the description of an ill-ventilated dwelling:—"Under such circumstances, considerable and immediate relief may be given by a plan suggested by Dr. Arnott, of taking a brick out of the wall near the ceiling of the room, so as to open a direct communication between the room and the chimney. Any occasional temporary inconvenience of down-draught will be more than compensated by the beneficial results of this simple ventilating process." As applications have since been made to me for further information on this subject, I beg through your paper—the vehicle of so much good to the public—to give the following detail respecting the contrivance and the *rationale* of its action.

I assume that most of your readers already understand, or will now learn, that the air which we breathe, and which is now used to stuff air-pillows, consists of material elements as much as the water which we drink, or the food which we eat,—indeed, consists altogether of oxygen and nitrogen; the first of which forms also eight-ninths by weight of the substance of water, and the other nearly one-fifth by weight of the substance of flesh: and that there is, surrounding our globe, to a depth of about 50 miles, a light fluid ocean of such air called the atmosphere, into which near the surface of the earth certain impurities are always rising, produced by the functions of animal and vegetable life, and by the decomposition of substances in putrefaction, combustion, &c., just as into the sea and great rivers some impurities are always entering from the shores—all which impurities, however, are quickly so diluted or dissipated in the great masses as to become absolutely imperceptible, and eventually, by the admirable processes of nature, are decomposed and changed, so that the great oceans of air and water retain ever their state of perfection. I assume further, that your readers know that fresh air for breathing is the most immediately urgent of the essentials to life, as proved by the instant death of any one totally deprived of it through drowning or strangulation or other means; and by the slower death of men compelled to breathe over again the same small quantity of air, as when lately 73 passengers were suffocated in an Irish steamboat, of which the hold was shut up for an hour by closely-covered hatches; and by the still slower death, accompanied generally by some induced form of chronic disease, of persons condemned to breathe habitually impure air, like the dwellers in crowded, ill-ventilated rooms and foul neighbourhoods; and, lastly, as proved by the fact, that pestilence, or infectious diseases, are engendered or propagated almost only where impurities in the air are known to abound, and particularly where the poison of the human breath and other emanations from living bodies are allowed to mingle in considerable quantity—as instanced in the gaol and ship fevers, which so lately as in the days of the philanthropic Howard carried off a very large proportion of those who entered gaols and ships; and, as instanced in that fearful disease, which at the black Assizes at Oxford, in July, 1577, spread from the prisoners to the Court, and within two days had killed the judge, the sheriff, several justices of the peace, most of the jury, and a great mass of the audience, and which afterwards spread among the people of the town. This was a fever which did its work as quickly as the cholera does now.

Assuming that these points are tolerably understood, I shall proceed to show that from faults in the construction and management of our houses, many persons are unconsciously doing, in regard to the air they breathe, nearly as fishes would be doing in regard to the water they breathe, if, instead of using the pure element of the vast rivers or boundless seas streaming past them, they remained in holes near the shores filled with water defiled by their own bodies or from other foul sources. And I shall have to show that the spread of cholera in this country has been much influenced by the gross oversights referred to.

All the valued reports and published opinions on cholera go far to prove that in this climate, at least, any foreign morbific agent or influence which produces it comes comparatively harmless to persons of vigorous health, and to those who are living in favourable circumstances; but that if it find persons with the vital powers much depressed or disturbed from any cause, and even for a short time, as happens from intemperance, from improper food or drink, from great fatigue or anxiety, but above all, for want of fresh air, and consequently from breathing that which is foul, it readily overcomes them. It would seem as if the peculiar morbid agent could as little, by itself, produce the fatal disease as one of the two elements concerned in a common gas explosion, namely, the coal gas and the atmospheric air, can alone produce the explosion. The great unanimity among writers and speakers on this subject in regarding foul atmosphere as the chief vehicle or favourer, if not a chief efficient cause, of the pestilence, is seen in the fact of how familiar to the common ear have lately become the words and phrases "malaria, filth, crowded dwellings, crowded neighbourhoods, close rooms, faulty sewers, drains, and cesspools, or total want of these, effluvia of graveyards," &c., all of which are merely so many names for foul air, and for sources from which it may arise. Singularly, however, little attention has yet been given from authority to what is really a chief source of poisonous air, namely, the poison of the breath, and to means of ventilation by which all kinds of foul air may, with mechanical or positive certainty, be removed.

A system of draining and cleansing, with sufficient water-supply for instance, to the obtainment of which chiefly the Board of Health has hitherto devoted its attention, can, however good, influence only that quantity and kind of aerial impurity which arises from solid or liquid filth retained within or about a house; but it leaves absolutely untouched the other, and really more important kind, which, in known quantity, is never absent where men are breathing, namely, the filth and poison of the human breath. This latter kind evidently plays the most important part in all cases of a crowd, and therefore in such catastrophes as those of the Tooting School, with 1,100 children, of whom nearly 300 were seized by cholera, of the House of Refuge for the Destitute, and of two great crowded lunatic asylums here, where the disease made similar havoc—for places so public as these, and visited daily by numerous strangers, could not be allowed to remain visibly impure with solid and liquid filth, like the rookery of St. Giles's, and other such localities. Now, good ventilation, which, although few persons, comparatively, are as yet aware of the fact, is easily to be had, not only entirely dissipates and renders absolutely inert the breath-poison of inmates, however numerous, and even of fever patients, but in doing this it necessarily at the same time carries away at once all the first-named kinds of poison, arising from bad drains or want of drains, and thus acts as a most important substitute for good draining, until there be time to plan and safe opportunity to establish such. It is further to be noted that it is chiefly when the poison of drains, &c. is caught and retained under cover, and is there mixed with the breath, that it becomes very active; for scavengers, nightmen, and grave-diggers who work in the open air, are not often assailed with disease; and in foul neighbourhoods, persons like butchers, who live in open shops, or policemen, who walk generally in the open streets, or in Paris the people who manufacture a great part of the town filth into portable manure, suffer very little.

To illustrate the efficacy of ventilation or dilution with fresh air in rendering quite harmless any aerial poison, I may adduce the explanation given in a report of mine on fevers, furnished at the request of the Poor Law Commissioners in 1840, of why the malaria or infection of marsh fevers, such as occur in the Pontine marshes near Rome, and of all the deadly tropical fevers, affects persons almost only in the night. Now the malaria, or poison from decomposing organic matters, which causes these fevers, is known to be formed during the day, under the influence of the hot sun, still more abundantly than during the colder night; but then, in the day, the direct beams of the sun warm the surface of the earth so intensely, that any air touching that surface is similarly heated, and rises away like a fire-balloon, carrying up with it, of course, and much diluting, all poisonous malaria formed there. During the night, on the contrary, the surface of the earth, no longer receiving the sun's rays, soon radiates away its heat, so that a thermometer lying upon the ground is found to be several degrees colder than one hanging in the air a few feet above. The poison formed near the ground at night, therefore, instead of being heated and lifted, and quickly dissipated, as during the day, is rendered cold and comparatively dense, and lies on the earth a concentrated mass, which it may be death to inspire. Hence the value in such situations of sleeping-apartments near the top of a house, or of apartments below, which shut out the night air, and are large enough to contain a sufficient supply of the purer day air for the persons using them at night, or are furnished with mechanical means of taking down pure air from above the house, to be a supply during the night. At a certain height above the surface of the earth, the atmosphere being nearly of equal purity all the world over, a man rising in a balloon, or obtaining air for his house from a certain elevation, might be considered to have changed his country, any peculiarity of the atmosphere below, owing the great dilution effected before it reached the height, becoming absolutely insensible.

Now, in regard to the dilution of aerial poisons in houses by ventilation, I have to explain, that every chimney in a house is what is called a sucking or drawing air-pump, of a certain force, and can easily be rendered a valuable ventilating-pump. A chimney is a pump—first, by reason of the suction or approach to a vacuum made at the open top of any tube across which the wind blows directly; and, secondly, because the flue is usually occupied, even when there is no fire, by air somewhat warmer than the external air, and has therefore, even in a calm day, what is called a chimney-draught proportioned to the difference. In England, therefore, of old, when the chimney-breast was always made higher than the heads of persons sitting or sleeping in rooms, a room with an open chimney was tolerably well ventilated in the lower part, where the inmates breathed. The modern fashion, however, of very low grates, and low chimney openings, has changed the case completely, for such openings can draw air only from the bottom of the rooms, where generally the coolest, the last entered, and therefore the purest air is found; while the hotter air of the breath, of lights, of warm food, and often of subterraneous drains, &c. rises and stagnates near the ceilings, and gradually corrupts there. Such heated, impure air, no more tends downwards again to escape or dive under the chimney-piece, than oil in an inverted bottle which is immersed in water will dive down through the water to escape by the bottle's mouth, and such a bottle or other vessel containing oil, and so placed in water with its open mouth downwards, even if left in a running stream, would retain the oil for any length of time. If, however, an opening be made into a chimney-flue, through the wall, near the ceiling of the room, then will all the hot impure air of the room as certainly pass away by that opening as oil from the inverted bottle would instantly all escape upwards through a small opening made near the elevated bottom of the bottle. A top window-sash, lowered a little, instead of serving, as many people believe it does, like such an opening into the chimney-flue, becomes generally, in obedience to the chimney-draught, merely an inlet of cold air, which first falls as a cascade to the floor, and then glides among the feet of inmates towards the chimney, and gradually passes away by this, leaving the hotter impure air of the room nearly untouched.

For years past I have recommended the adoption of such ventilating chimney-openings as above described, and I devised a balanced metallic valve to prevent, during the use of fires, the escape of smoke into the room. The advantages of these openings and valves were so manifest, that the referees appointed under the Metropolitan Building Act added a clause to their Bill allowing the introduction of the valves, and directing how they were to be placed, and they are now in very extensive use. A good illustration of the subject was afforded in St. James's parish, where some quarters are much too densely inhabited by the families of Irish labourers. These localities formerly sent an enormous number of sick to the neighbouring dispensary. Mr. Toynbee, the able medical officer of that dispensary, came to consult me respecting the ventilation of such places, and on my recommendation had openings made into the chimney-flues of many of the rooms near the ceilings, by removing a single brick, and placing there a piece of wire gauze with a light curtain flap hanging against the inside, to prevent the issue of smoke in gusty weather. The decided effect produced at once on the feelings of the inmates was so remarkable that there was an extensive demand for the new appliance; and, as a consequence of its adoption, Mr. Toynbee had soon to report, in evidence given before the Health of Towns Commission, and in other published documents, both an extraordinary reduction of the number of sick applying for relief, and of the severity of the diseases occurring. Wide experience elsewhere has since obtained similar results. Most of the hospitals and poor-houses in the kingdom now have these chimney-valves; and most of the medical men and others who have published of late on sanitary matters have strongly commended them. Had the present Board of Health possessed the power, and deemed the means expedient, the chimney-openings might, as a prevention of cholera, almost in one day, and at the expense of about a shilling for a poor man's room, have been established over the whole kingdom.

Mr. Simpson, the registrar of deaths for St. Giles's parish, an experienced practitioner, whose judgment I value much, related to me lately that he had been called to visit a house in one of the crowded courts, to register the death of an inmate from cholera. He found five other persons living in the room, which was most close and offensive. He advised the immediate removal of all to other lodgings. A second died before the removal took place, and soon after, in the poor-house and elsewhere, three others died who had breathed the foul air of that room. Mr. Simpson expressed to me his belief that if there had been the opening described above into the chimney near the ceiling, this horrid history would not have been to tell. I believe so too, and I believe that there have been in London lately very many similar cases.

The chimney-valves are part of a set of means devised by me for ventilation under all circumstances. My report on the ventilation of ships, sent at the request of the Board of Health, has been published in the Board's late Report on Quarantine, with strong testimony furnished to the Admiralty as to its utility in a convict-ship with 500 prisoners. My observations on the ventilation of hospitals is also in the hands of the Board, but not published. All the new means have been freely offered to the public, but persons desiring to use them should be careful to employ competent makers.

I am, Sir, &c.

Bedford Square, *Sept.* 22, 1849.

Nothing of much importance with respect to the art of ventilating has been done by public authority since that time, although the expensive and decided failures by individuals who have undertaken to ventilate the Houses of Parliament, hospitals, prisons, and other public buildings, have proved how much sound knowledge on the subject was wanted.

In the end of 1852, and the beginning of the following year, there prevailed in Croydon, a suburb of London containing above 16,000 inhabitants, a remarkable epidemic fever and bowel disease. Extensive works had just been executed there, with a view to improve the sanitary condition of the place, according to plans modified and approved by the then General Board of Health. An opinion sprang up, however, among the inhabitants and others, that the pestilence was occasioned by the defects or failure of the new works; and this opinion became so strong, that Viscount Palmerston, then Principal Secretary of State for the Home Department, deemed it expedient to appoint a Commission of Inquiry. The members named were Thomas Page, Esq., Chief Consulting Engineer to the Board of Works, and the writer of this. The latter, deeming the occasion opportune for giving a popular lesson on certain sanitary matters, which it much interested the public to understand, appended to his Medical Report on the facts of the case, the following notice on the origin and nature of fevers and other epidemics.

ON THE ORIGIN AND NATURE OF FEVERS AND EPIDEMICS.

An intelligent person, not of the medical profession, desirous to be informed respecting the origin and nature of some prevailing epidemic, would be little satisfied if told only that even medical men held very different opinions regarding it; yet not long ago such must have been the reply to many of his questions. Late discoveries, however, in general science have given so much new light, as not only to remove many professional doubts, but to enable ordinary inquirers, who possess elementary knowledge of chemistry, mechanics, and life, to understand many of the most interesting truths respecting general health and disease.

The great discoveries have been in the three departments of (1) chemistry, (2) mechanics, (3) life.

1. *Chemistry.*

(*a*) A century ago no person on earth knew that there existed in nature the substance which, since Dr. Priestley's discovery of it in 1774, has been named *oxygen* (so named because of its early-perceived relation to acids), although now students soon learn that it forms a large proportion by weight of a majority of the things,—whether solid, liquid, or aeriform, living or dead,—which men have yet encountered in or on this globe.

(*b*) Nor did any one then know that water is a compound of eight parts by weight of this oxygen, and one part by weight of another element, called *hydrogen* (so called because of its relation to water); both of which elements, when in their separate or insulated state, and at the temperature of this earth, exist in the form of air or gas, and might serve therefore as stuffing for air-cushions. Hydrogen is now popularly known as the chief material burned in our street lamps, and as what, being very light, is used for filling balloons.

(*c*) Nor was it known that all vegetable bodies,—whether wood, leaves, or flowers, or fruit or seed,—consist chiefly of these two elements of water combined in different proportions with another elementary substance which has got the name of *carbon* (so called because it was first known as being the chief part of coal).

(*d*) Nor was the truth suspected that animal flesh, and soft animal substances generally, consist chiefly of the three components of vegetables just named, with the addition of a fourth, called *nitrogen* (so called because first obtained from nitre); which last when existing separately, also appears as an air or gas, and which, when mixed with one-fourth part by weight of oxygen, forms our common atmospheric air.

(*e*) Nor were people aware that the whole of the countless variety of the material substances, including minerals, yet known to man, are compounds of a very few simple elements, of which the four above spoken of are a very important portion, joined, atoms to atoms, in different proportions and ways, somewhat as all the words of all the languages used on earth are composed of a few simple sounds recalled by the letters of a general alphabet,—which atomic elements, while in themselves absolutely unchangeable and indestructible, assume in combination or alone the three forms of solid, liquid, or gas, according to the quantity of heat pervading them.

(*f*) Nor, lastly, was it known that the heat and light accompanying rapid combustion are effects of the intensity of action with which two or more combining substances are at the moment uniting into chemical compounds, one of the burning substances generally being oxygen; the same substances, however, being also capable under other circumstances of combining slowly and quietly, with scarcely sensible increase of temperature and no light, as when the oxygen of the air is combining with exposed iron and converting it gradually into rust.

2. *Mechanics.*

A century ago no man had conceived it possible that human ingenuity would one day devise a machine like the modern steam-engine, which, at small comparative cost and with perfect obedience to man's will, should be able to perform the work of millions of human beings, and of countless horses and oxen, and of watermills and windmills, and which, in doing such complex and delicate labour as formerly was supposed to be obtainable only from human hands and skill, as of spinning, weaving, embroidering flower-patterns on cloth, &c., should work with speed and exactness far surpassing the execution of ordinary human hands.

3. *Life.*

And lastly, in regard to *Life* or animal action, nothing, even a few years ago, was farther from men's thoughts than that the great steam-engine just named, of which the internal actions seemed at first so little to resemble the internal functions of an animal body, should, with the advance of our knowledge of animal chemistry and mechanics, be discovered to imitate these very closely indeed, and by exhibiting some of them in comparative simplicity, should shed a useful light on the more recondite or hidden processes of the living system. Such, however, is the case. James Watt, when devising his first engine, knew well that the rapid combination of the oxygen of atmospheric air with the combustible fuel in the furnace produced the heat and the force of the engine; but he did not know that in the living body there is going on, only more slowly, a similar combination of the oxygen of the air with the like combustible matter in the food, as this circulates after digestion in the form of blood through the lungs, which combination produces the warmth and force of the living animal. The chief resemblances of the two objects are exhibited strikingly in the following table of comparison, where in two adjoining columns are set forth nearly the same things and actions, with difference in the names.

TABLE OF COMPARISON.

THE STEAM-ENGINE IN ACTION	THE ANIMAL BODY IN LIFE
Takes:	Takes:
1. FUEL, viz.—Coal and wood, both being old or dry vegetable matter, and both combustible.	1. FOOD, viz.—Recent or fresh vegetable matter and flesh, both being of kindred composition, and both combustible.
2. WATER - - - -	2. DRINK (essentially water).
3. AIR - - - - -	3. BREATH (common air).
And Produces:	And Produces:
4. STEADY BOILING HEAT of 212 degrees by quick combustion.	4. STEADY ANIMAL HEAT of 98 degrees by slow combustion.
5. SMOKE from the chimney, or air loaded with carbonic acid and vapour.	5. FOUL BREATH from the windpipe or air loaded with carbonic acid and vapour.
6. ASHES, part of the fuel which does not burn.	6. ANIMAL REFUSE, part of the food which does not burn.
7. MOTIVE FORCE, of simple alternate push and pull in the piston, which, acting through levers, joints, bands, &c., does work of endless variety.	7. MOTIVE FORCE, of simple alternate contraction and relaxation in the muscles, which, acting through the levers, joints, tendons, &c. of the limbs, does work of endless variety.

8. A DEFICIENCY OF FUEL, WATER, OR AIR, first disturbs, and then stops the motion.	8 A DEFICIENCY OF FOOD, DRINK, OR BREATH, first disturbs, and then stops the motion and the life.
9. LOCAL DAMAGE from violence in a machine is repaired by the maker.	9. LOCAL HURT OR DISEASE in a living body is repaired or cured by the action of internal vital powers.

Such are the surprising resemblances between an inanimate machine, the device of human ingenuity executed by human hands, and the living body itself, yea, the bodies of the men whose minds contrive and whose fingers make such machines. A prodigious difference, however, between the two is pointed at by the expression *vital powers,* contained in the last line of the preceding table. That difference, described in a few words, is, that while the machine has to be originally constructed, and afterwards worked and repaired and supplied with every necessary, by intelligence and forces altogether external to it, the animal body performs all the offices mentioned, and others yet more surprising, for itself, by virtue of forces or powers originally placed within it by the divine Author of Nature. And wonderful indeed it is to reflect that every animal exists at first as a minute speck of matter called a germ or ovum, of simplest form, but in which all the vital powers above spoken of are already present, under the influence of which new matter begins quickly to be selected and taken in from around to form the compound fluid called *blood*, and out of this blood afterwards are gradually built up all the parts and organs of bone, muscle, skin, hair, eye, ear, &c., which the body in its most perfect state possesses; and not only are the parts so built up to full size and strength during the years of growth, but they are receiving constant support and repair (as a ship's crew may be preserved vigorous for 100 years by the constant exchanging of old men for young), through the long period of middle age and gradual decline; and, most wonderful of all, during the middle term of its existence, the body is able to throw off germs such as it was originally itself, to continue the race through future ages. These phenomena, or miracles, are all referred in common language to *vital powers*, because they go on like the phenomena, for instance, of what is called the *power of gravitation*, according to laws which men can learn and turn greatly to their advantage; but the thoughtful man is led by the contemplation of them into the presence, so to speak, of his own and the world's Creator.*

The animal body consists of a vastly greater variety of parts than any machine. If only one or two not very important parts are hurt or diseased at one time, as when fingers are wounded, the general health may continue nearly as usual, and may be gradually working the cure of the hurt. Such occurrence is called a local disease; but if any event change hurtfully the composition or condition of the blood,—out of which, as described above, all other parts of the body are formed, and are continually nourished or supported, and which has itself to be maintained in a healthy state by, 1st, the introduction, at short intervals, of fresh matter from the digestive organs; 2dly, by the removal from it of impurities through the skin, kidneys, &c.; and lastly,

* In 1840 the author, at the request of the English Poor Law Board, visited Edinburgh and Glasgow to see and report on the sanitary condition of these places. An extract from his report, as bearing directly on the view of the animal economy here sketched, is printed in the Appendix to this volume at page 215.

by the action, about fifteen times every minute, of fresh air admitted to near contact with it in the lungs,—then every part of the body may be thrown at once into a disordered or unhealthy state, nearly as when a stream which supplies water to bleachers, brewers, dyers, bakers, &c. is defiled, and spoils the work of all who use it. Such change constitutes what is called general disease. General disease may be mere weakness of all the parts of the body, arising from insufficient or bad food or drink, or from want of pure air; but a change may be produced in the blood so sudden and so great as to kill instantly, as when prussic acid enters it from the stomach, or various mephitic gases from the lungs, and then the agent is called a poison; or, lastly, the deleterious admixture or change may not be strong enough to kill instantly, but may only produce violent commotion or disturbance of the system, lasting for a longer or shorter time, which, by the natural actions of self-repair in the system, may be overcome and be followed by re-established health. Many of such general diseases as the last described are called fevers, because of the increased heat which usually accompanies them. It is thus that a little of the virus of smallpox, introduced into the blood on the point of a lancet, produces soon the fever of smallpox, lasting for twelve or fourteen days; and that the inhaling for a short time the atmosphere of a foul jail or ship will produce the jail or ship fever.

To have a conception of such a general disease or fever, it is necessary only to recall to mind in any simple order all the parts of the body, and to think of the common ways in which the states or functions of these may be altered. Thus, beginning with the head and proceeding downwards, there are disturbances of—

1. *Head.*—Headache, stupor, delirium, confusion of mind, disturbed sleep, imperfect hearing, sight, taste, smell; giddiness, &c.

2. *Chest.*—Breath quickened or retarded, hot or offensive, heart action disturbed as indicated by the pulse, palpitation, fluttering, &c., cough, changed voice, &c.

3. *Abdomen.*—Digestion disturbed, appetite impaired, thirst, nausea, vomiting, diarrhœa or the contrary, colic, &c. The kidney secretion diminished, increased, altered.

4. *Limbs.*—Having pain, langour, weakness, spasms, restlessness, &c.

5. *Body.*—Generally hot, cold, trembling, emaciated, with skin dry, perspiring, &c.

Any fever is made up of a certain number of these, but, generally, with one or other of the deviations from the healthy state more remarkable than the others, according to the nature of the cause and to the previous condition of the patient. Thus arise the diversities called brain fever, bilious, nervous, gastric, intermittent, putrid fever, and others.

We shall now review more in detail than in the beginning of this sketch the two remarkable chemical facts:—1st, that all vegetable bodies, whether those that serve as the food of man, or those which are to him poisons, consist chiefly of only three elementary substances, namely Carbon, Hydrogen, and Oxygen, which in the different compounds are united in different proportions or in different ways; and, 2nd, that all animal substances, and some vegetable, which contain poisons like prussic acid and morphine, consist chiefly of the same elements, with one more added, viz., Nitrogen. The chemist uses the first letters of the names, C, O, H, N, as symbols for these four elements; and in marking the composition of an object, indicates the number of atoms of each which exists in one particle of the compound by numbers placed beneath the letters, thus:—

In *vegetable matters:*

$C_{12}\ O_{10}\ H_{10}$	is starch.
$C_{12}\ O_{11}\ H_{11}$	sugar.
$C_4\ O_2\ H_6$	spirit of wine.
$C_4\ O_4\ H_4$	acetic acid, or vinegar.
$C_{12}\ O_8\ H_{14}$	citric or lemon acid.
$C_{12}\ O_{11}\ H_{11}$	gum.
$C_4\ O\ H_5$	ether.
$C_2\ O_3$ —	oxalic acid.
$C_2\ H\ N$	prussic acid.
$C_{34}\ O_6\ H_{19}\ N$	morphine.
$C_{42}\ O_4\ H_{22}\ N_2$	nux vomica poison, or strychnia.
C_{10} — $H_7\ N$	tobacco poison, or nicotin.

In *animal matters* the resembling composition is seen in the following list, which exhibits, not the numbers of atoms, but the comparative weights per cent. of the ingredients:—

	Fibrin.	Albumen.	Casein.	Glue.
C. Carbon - -	54·8	54·5	54·9	50·0
H. Hydrogen -	7·0	6·9	7·1	6·4
N. Nitrogen -	15·8	15·7	15·8	18·3
O. Oxygen -	21·2	22·1	21·7	25·1

And what is wanted to make up the 100 parts in these are small quantities of Sulphur (S), and Phosphorus (P).

From the consideration of the examples here given, it is evident that the number of proportions in which the three or four elements may be combined, and therefore the number of different substances producible out of the same few elements, is almost without limit. And it has to be added, that even the same elements in the same proportions may be differently arranged, so as to produce still other differences, as may be conceived by reflecting that three letters, as *a e t*, may be differently arranged to form the words *tea, eat,* or *ate*; and the four letters, *o s t p,* in similar way, to produce the words *pots, tops, spot, stop,* and others. This explains the endless variety of tastes, odours, and other qualities observed as belonging to parts of vegetables and animals.

Why compounds with so nearly the same elements as oxalic acid and sugar, prussic acid and common vinegar, &c., should have such opposite effects upon the living frame, we can no more explain than we can why Ipecacuan should excite vomiting, and wheat flour should nourish; but we know the facts well, and can turn them to very useful account. Among the substances rendered interesting by their powerful action as poisons, there are among vegetables strychnia, aconite, tobacco, prussic acid, belladonna, &c. Among animals there are the venom of serpents, the poison of stings, the saliva of the mad dog, &c.

We have now to remark, as a general fact respecting chemical unions, that the elements cohere more strongly in proportion as the unions are more simple, whether in regard to the number of elements, or to the number of atoms of one element, which meet in one particle of the compound, nearly as, in human society, the wedded pair hold together more strongly than the members of a numerous family, and these than any larger association, as of a ship's company or a regiment. Thus, the one atom of oxygen and the one atom of hydrogen, which join to form water, of which the chemical symbol therefore is H O, cling together much more strongly than where more than two elements join, and where more than one atom of the same element exist in one particle of the compound; as, for instance, in the various vegetable and animal substances of which the composition is shown in the preceding lists. As a consequence of this, it follows that simple chemical unions in general are easily or readily formed, both in nature and by art, but are not easily subverted; while complex unions, on the contrary, requiring a delicate balance to be obtained between many things, are difficult to form, and very easily subverted. The chemist was not able until lately to decompose water; and he still labours in vain to build up out of the well-known cheap elements, above described, of water, carbon, and atmospheric air, most of the precious compounds which the as yet mysterious actions of vegetable and animal life present to us. He cannot yet chemically make opium or wheat flour, or sugar; but progress is being made in that direction, for he not only knows that the foul, horribly-offensive water which has served to wash or purify coal-gas at the gasworks, contains the elements of lavender, camphor, ottar of roses, and other perfumes, but he can now extract from it a near approximation to some of them; and, strange to say, he can now produce by his art the exquisite flavour of the strawberry and pine-apple, in any climate or season, without aid from garden beds or sunshine.

The preceding statements furnish the explanation of how animal and vegetable substances when they die, and the elements are no longer held together by the powers of life, so quickly undergo change, and with such variety of results. What is called the decay, rotting, or putrefaction of these substances, is the spontaneous decomposition which then takes place, much hastened and modified when water is present and the temperature is high; and in the course of which a series of new and gradually more simple combinations are being formed, tending to leave the elements in more stable arrangements. This explains the changing odours, tastes, and other qualities which during such processes are always to be observed. A good example of such a series is that which occurs in the arts of brewing and spirit-making. First, barley being wetted and warmed, or malted, has its starch converted into sugar; then by another process or step that sugar is converted into alcohol or ardent spirit; and by a third, the alcohol may be converted into vinegar. The small differences of composition among these are shown in the illustrative list given above.

Because certain of the possible transient combinations of the elements of organic substances during their putrefactive dissolution are noxious to animal life, and because from becoming chiefly aëriform they rise into the atmosphere as effluvia, we can understand how dangerous it may be for persons to be in or near places where such processes are actively going on;

and we can understand why the effect in producing diseases should differ according to the quantities and kind of dead matter, and the degrees of warmth and moisture which favour the chemical actions. As a man in breathing takes in air which is immediately applied to the internal surface of all the air-cells of the lungs, a surface much more extensive than that of the stomach, which can absorb so quickly prussic acid or wine, we can understand how suddenly an aëriform poison pervading the atmosphere may be absorbed into the system. The fact of such quick absorption by the lungs is familiar to us in other cases; as when a man having taken a few whiffs or inspirations from a bottle of ether absorbs so much of the ether into his system that for twenty-four hours any stranger approaching him perceives ether-vapour escaping in his breath; and again, as when a patient who inhales chloroform, mixed with air, receives it so quickly into his blood that it reaches the brain often in less than a minute, and deprives him of all sense. Some persons become intoxicated by breathing for a time the atmosphere of a spirit-cellar or gin-shop; and there are undoubted instances of the infection of smallpox, measles, &c., having been communicated during a face-to-face encounter of only a few moments.

But one of the most hurtful to man of all the aërial poisons is that of his own expelled breath, when detained long around him, and breathed again. A considerable proportion of the solid aliment and drink which he receives is thrown off by the lungs and skin, as kinds of excrementitious matter, in the forms of carbonic acid, water, and aëriform organic matter. The last-named portion gives a certain odour to the breath and bodies of many persons even in good health, by which, a dog often can trace his master, and with impaired health it becomes copious, offensive, and pernicious. This organic matter, probably at first, when it may be called fresh, is harmless, for a mother does not fear to kiss her beautiful child, nor do persons in a crowded church, or other place where healthy people assemble, much fear their neighbours, but there is no doubt that it soon becomes putrid and noxious. In early states of society, before glass windows were used, and when men lived almost in the free air, they had no notion of this poison, and that ignorance continuing through later times explains to us many of the facts connected with the generation and spread of plagues or epidemics.

In the well-known case of the Black Hole Prison, at Calcutta, into which 146 military prisoners were thrown at night, and only twenty-three were alive next morning, the cause was not the putrefaction of the breath but the quantity of carbonic acid formed there, and the want of more fresh air than could enter by the one small window of the dungeon;—the same is true of the case of seventy-three persons destroyed four years ago in a Dublin steam-boat, of which the ignorant captain, to keep out the waves of a stormy night, shut the hatchway so close as to keep out also the fresh air required for the breath of those below. These two cases were, therefore, rather of suffocation, as in drowning or being strangled, than of death from corrupted air; but the pale faces of the sedentary inhabitants of imperfectly-ventilated city rooms, as compared with the healthful complexions of persons who live in pure air, whether of country or town, are in considerable part owing to vitiation of the air through decomposing impurity. In crowded jails, hospitals, and ships, with little ventilation, both causes are in such active operation as soon to produce or breed the destructive fevers which take their names from these localities. In persons labouring under some of these, the flesh and blood are known by the smell to be already falling into putrescence even before the patients die; and the breath and exhalations from the patients and the impurity remaining in their clothes are powerfully infectious. The histories of what have been called the Black Assizes at Oxford in 1577, and at the Old Bailey in 1750, are striking proofs of these truths. Some prisoners brought into court infected with fatal disease, judges, sheriffs, counsel, and jurymen, and many of the audience, who died within a short time and spread the infection still farther. And, lastly, it may be observed that the great ravages of cholera were in crowded ill-ventilated houses, like the Tooting School, the House of Refuge for the Destitute, and two lunatic asylums, all near London. It appeared in these cases as if a peculiar cause predisposing to cholera had been rendered active by the impurity generated among people living in confined air; but for which impurity the cholera might not among them have appeared.

Such facts prove that ventilation, or the constant substitution of pure air taken from the general atmosphere for the contaminated air of enclosed localities, is one of the most important parts of the art of preserving and restoring health. That the importance of it has been so lately understood even by scientific men, and is still so little understood by the mass of the people, is explained by the other facts above referred to, namely, that a hundred years ago nobody on earth knew anything of oxygen and nitrogen; or that the air we breathe, consisting of these, is as much a material substance as the water we drink or the food we eat,—indeed, consists of similar elements, only in different combination and form,—and that it can carry poison like these. Then, although men have long been aware that arsenic, prussic acid, and the other solid and liquid poisons may all be rendered harmless,—nay, in certain cases may even be used as medicines when copiously diluted with pure water,—many have yet to learn that aërial poisons also can be rendered quite harmless by large admixture of pure air. In a locality where a deadly contagion prevails, the atmosphere at a short distance above it is no more contaminated by it than the deep stream of the Mississippi is contaminated by a child washing a foul rag near its bank; and mechanical art can now draw down pure air from the sky, and fill with it any dwelling, as certainly and steadily as gas for burning is supplied to all persons who want it from the central gasholder of a town.

Besides the poisons generated in the air during the decomposition of dead organic substances, as above explained, there are atmospherical conditions, hurtfully affecting human health, produced also by electrical agency and barometrical changes, and by admixture of gases rising from mineral strata in the bowels of the earth. And sometimes the wind comes loaded with microscopic vegetables and animals, or their seeds and ova, which, falling over a region, effect what is called a blight on the corn, vines, or other vegetable productions there. Some of these minute organized beings propagate or multiply with rapidity appearing almost miraculous—as when, on a larger scale, in one or two warm days the whole carcase of a dead animal seems to be converted into maggots. Then it is to be observed, that some of the special poisons or infections which enter the human blood, such as the virus of smallpox or of measles, seem to act on the blood as a little yeast put into a mass of dough, or into a vessel of wort, acts on that, causing a change in the mass, and assimilating part of it to the nature of the new agent which has entered. In the living body, after a time, this newly-formed matter is expelled from all parts as a cutaneous eruption, and the disease subsides. In regard to the eruptive fevers, there is the curious additional particular, that they rarely occur a second time in the same person. Many of the facts here referred to require further elucidation; and observers are therefore induced to watch with great interest all the phenomena of new outbreaks, like those in recent times of cholera and the potato disease. All the facts, however, concur in marking the singular value to public health and well-being of cleanliness and complete command of ventilation.

Having explained, by reference to now known principles of mechanics, chemistry, and life, how the malaria from decomposing vegetable and animal substances, generated under certain circumstances, and mingled often with the detained and putrifying breath of living animals, becomes the chief cause and spreader of epidemic diseases, it would be an interesting task to show in detail how closely all trustworthy histories of epidemics in past ages correspond with what science now offers as the explanation; but there is room here for reference only to a few more illustrative facts.

In the last century, from the year 1742 to 1748, the English Government, co-operating with German allies, maintained about 20,000 troops in Flanders and part of Germany, where they had to suffer the chances and hardships of war in a country of which many parts are low and marshy. The physician to the forces was Dr. Pringle, afterwards Sir John, and President of the Royal Society,—a man, like Sydenham of the preceding century, of remarkable natural sagacity and of much knowledge for the time. He knew not oxygen, nor, therefore, the composition of organic bodies, but he had no favourite theory to support; and so, in his admirable book on "Diseases of the Army in Camp and Garrisons," he described things and occurrences with rare fidelity. Much of his history had to record the effects on the soldiers of the noxious atmosphere of marshes, camps, barracks and hospitals, in different seasons and in different conditions of heat and moisture; and therefore it has the most direct bearing on the questions here discussed. The testimony given by him may be recapitulated thus:—

When a body of healthy men arrived in a marshy region in temperate weather, cases of common ague soon appeared; if the station was near a marsh, and on the side of it towards which the wind blew, the number of sick rapidly increased; if the wind then changed, there was again speedy relief. If the weather became warm, quickening the decomposition of plants and animals that might die and rot in the marsh, the sickness increased: with change towards cold, the contrary effect occurred; and with frost the fever ceased. If the marsh was foul with animal impurities, bowel irritation, even to the extent of dysentery, would arise, and the fever would be aggravated to the form of double-tertian, or remittent, and soon to the continued form; with higher temperature or more filth, such as naturally accumulates in encampments, the fever would become more ardent or intense, and be called bilious remittent. Even far from low or wet ground, if the filth of a camp were allowed to accumulate during hot weather, in the form of rotting straw and foul privies, &c., the bilious remittent would readily spring up; and if the tents or barracks were crowded, it would assume a putrid and malignant character, and prove contagious and highly destructive. If the sick themselves were gathered into a crowded and ill-ventilated hospital, the mortality and rapid communication of the fever or dysentery to other patients and attendants became fearful; and, lastly, if the hospital sick, from the necessities of war, had to be placed in ships, as then managed, for transport, the chance of life to any individual was small indeed. Of a number of sick who were shipped from hospitals on the Rhine, near Worms, for transport to Ghent, more than half perished on the voyage, and many of the remainder soon after. A proof of the virulence of the disease was that of twenty-three healthy journeymen, whom a tradesman at Ghent set to refit old tents which had been used in the ships as bedding for the sick, seventeen died of the distemper. The disease, when in the most aggravated form, produced gangrenous buboes and boils, like the plague of the Levant;

and in the previous degrees of severity it was identical in character with the fevers elsewhere called jail, hospital, and ship fevers, which can anywhere in temperate climates be generated or bred under the like circumstances.

Histories, of which that above given may serve as the type, describe the occurrences in various places and in the various years of these campaigns. In the winters, when the low temperature arrested the decomposition of dead organic matters, the fevers almost disappeared, and the prevailing diseases were pleurisies, rheumatism, and the other inflammations common in European winters.—A principal cause of the illness among troops in the field is doubtless the sudden check given by the cold of night, while the men are exposed on military duty or are lying on the ground, to the perspiration excited by the heat of the days. The perspirable matter which would escape if the skin continued to act, being then shut up, becomes the cause of febrile disturbance, or runs off with bowel looseness.

Every medical man of long experience must have witnessed interesting facts illustrative of the subject of malaria. The writer of this sketch will complete it by giving a few of the instances which have come within his own observation or knowledge.

1. Early in the present century a fleet of large ships sailed from Portsmouth for India, having many troops on board. Stormy weather in the Bay of Biscay rendered it necessary to close the ships' ports, and to trust for ventilation almost entirely to the common windsail, which is a large tube of canvas suspended near a mast, with its upper mouth held extended to

catch the wind, and the bottom hanging through the hatchway below. Typhoid fever, to an alarming extent, soon prevailed in the fleet, believed by some to have been brought from the barracks, but almost certainly generated on board. The deaths were numerous in all the ships except one, in which means were used to insure that the air which descended by the wind-sail instead of being diffused as chance might determine around the hatchway, should spread to the most remote corners of the crowded deck. In that ship only one death with fever occurred, and it was of a man previously diseased. On the return of the ship to England, the Duke of Kent, who was the colonel of the regiment that had suffered, sent for the chief medical officer of that ship, to thank him for his successful attention to the men who had been under his care.

2. The same ship, after disembarking the troops in the Straits of Malacca sailed to Canton in China, and there, by order of a capricious mandarin, had to anchor at first in a part of the river surrounded by flooded rice-fields. Within three days about twenty of the crew were seized with ague; permission was then obtained to sail higher up. No new cases appeared, and the sick soon recovered.

3. The writer of this, soon after settling in London, had his attention drawn to several remarkable cases of fever breaking out in houses where the drains were defective, in two of which, after change of the occupants, similar fever appeared among the new incomers.

4. Before the establishment of the Birmingham Railway Station behind Euston-square the site was a singularly impure field rented by a cow-keeper, through

which, not far from extensive cow-sheds, passed open sewers often full to overflowing. Cases of fever had occurred on all sides of it. The writer was called on five occasions, at intervals of a year or more, to give professional counsel at a charity-school near, in which were 150 girls, where remarkable outbreaks of disease occurred, unquestionably caused by the malaria of the field and the crowding in the school. In the year 1818 the outbreak began with rigid spasm attacking the arms of six of the elder girls, on the same day, and at the same hour. It was at first suspected that these had all partaken of some poisoned dish. They were relieved in the afternoon, but next day, at the same hour, they relapsed with similar affection of the legs also, and several new cases appeared with only the arms affected. On the third day, in those first attacked, most of the voluntary muscles were rigid, and there was fever. Within three weeks about thirty of the children had been thus ill. Several medical men met the writer to see this singular disease. In another year typhoid fever broke out in the school to about the same extent. It quickly subsided, when the patients were removed to another air. About ten of them were sent to the Fever Hospital. In another year ophthalmia prevailed; and in another, a singular constipation of bowels without other ailment. After the field was drained and covered with buildings no more such diseases were seen there.

5. In the year 1829 the wife of the writer's coachman and her three healthy children were sitting at an open window of the stable when men began to remove a stable dungheap belonging to the adjoining house, but lying nearly under the open window, into which

heap it was found that pigs' offal and other kindred impurities had improperly been thrown a little while before. The insufferable odour from the broken-up heap drove the mother and children from the window, but sickness to vomiting followed, and soon after fever with stupor came upon the two youngest children; one of these died the next day, and the other a day after. Dr. Armstrong and Dr. Maton attended in consultation in this remarkable case.

6. In 1825, during the construction of a new deep sewer along the Walworth-road near London, a fever broke out like the late Croydon fever, and prevailed extensively in the houses on both sides. The ground is low and flat. In many of the gardens there had been ornamental fish-ponds. The deep sewer drained all these, and the effluvia from the putrefaction of the bodies of the fish and insects which had lived in the water were added to that of the drains themselves. A friend of the writer, the father of a numerous and healthy family, had there a large garden with several ponds. As the works proceeded, all his children became unwell, and at last one had strong fever; the family were sent away, and at Streatham all soon recovered health; two servants, however, who were left, got the fever, and after removal to their own homes died of protracted bowel irritation, such as has lately been seen at Croydon. After an absence of some weeks the family returned, but as the children again declined in health, they were finally removed from the neighbourhood.

7. In 1837, at the request of the Poor Law Commissioners, the writer, in company with Dr. Kay, one of the Assistant Commissioners, visited places to the

east of London, from which many cases of fever had been sent to the London Fever Hospital, and they concurred in the opinion that the filth of the neighbourhoods was the chief cause, as had been seen in the case of the charity-school near Euston-square above detailed. The writer was requested by the same Commissioners to report on a pamphlet of Dr. Alison, professor of medicine in Edinburgh, who believed that the fevers in question were from contagion, and not from filth. In his report the writer maintained his previously-expressed opinions, since confirmed by innumerable facts. He was requested, in continuance, to visit and inspect Edinburgh and Glasgow,* to the fevers of which also Dr. Alison had referred; but he found the disease there still of the same character, originating in sites remarkable for filth and bad ventilation, and then spreading by the aid of these and by communication from person to person.

8. In March 1836 mention was made in Parliament of a school at Norwood for London pauper children, at the time containing nearly 700, where 30 had died within a short time, and the rest were said to be nearly all unwell, owing, it was thought by many, to scanty or bad food supplied to them by the proprietor. On the following day the Poor Law Commissioners requested the writer of this to visit the school and to report. On his way out he visited for the sake of comparison another school, containing 150 children of the same class, on Brixton Hill. This school was not crowded, and the children, among whom only two had

* See the Report in the Appendix.

died in three years, looked remarkably healthy. On entering a room of the Norwood school, in which nearly 300 boys were present, he was at once struck by the offensive state of the atmosphere. Although on a cold day, the air, from want of ventilation, was hot and foul; and in such air the children lived through both days and nights, for the sleeping-rooms were immediately over the school-room, and with free communications. The children all had a pale unhealthy look, and on examination it was found that every form of scrofulous disease abounded among them,—swelled glands, skin eruptions, sore eyes, scald-head, diarrhœa, dropsy, and fever. The food given to them, however, he found to be better than what is usually supplied in establishments of the kind, and the evident cause of their illness was want of fresh air. He reported accordingly. The faults being remedied, the school after a time became as remarkable for the good health of the scholars as for their number—which soon exceeded 1,000—and the excellent educational arrangements.

9. About twelve years ago a new monkey-house was constructed in the Zoological Garden here; no expense was spared to show hospitality to the tropical strangers; the house was made like an English drawing-room, with open fire-places near the floor,—an arrangement then generally supposed in England to secure comfort and good ventilation. Above sixty healthy monkeys were placed in it. In a month fifty-one of these were dead, and the rest seemed dying. Every one which died was opened, and tubercles were said to be found in the lungs, proving consumption. The writer of this was consulted, and he found in the monkey-house only an aggravated case of what had

existed at the Norwood school. As the flame of a candle is soon extinguished in its own smoke, if an inverted coffee-cup be held over and around it, although the cup remain open below, so was the life of the monkeys extinguished by their own hot and foul breath, caught and retained in the upper part of the room where their cages stood, although there were open chimneys below; and the confined air, soon saturated with the matters thrown off from their lungs, being unable to take more, left in the lungs what was deemed the tuberculous matter of consumption. Channels for ventilation were subsequently opened near the ceiling into a heated shaft or chimney, and thenceforward healthy monkeys could live in that room. Many are the human beings still treated nearly as these monkeys were, only not so completely imprisoned in their rooms, and during their occasional absence, the air is partially changed.

10. In 1843 the authorities determined to send 500 convicts to Van Diemen's Land in one ship, the Anson, an old seventy-four. Dr. Millar, the surgeon, feared that this greater than usual number of prisoners, of which only a small part could be allowed to be on deck for air at a time, would breed disease on the lower decks. He caused, however, four simple ventilating pumps to be made on board by the carpenter, costing, as stated in his report to the Admiralty, only 30*s.* each, like one which he had seen in the house of the writer of this, and with these he secured excellent health to his charge during the whole voyage.—It is painful to think of the destruction of human life which has taken place in emigrant ships during the last few years from imperfect ventilation. Dr. Andrew

Combe, the author of the popular works on the means of preserving health, made a voyage to America three years ago in an emigrant ship in which a destructive fever was bred for want of ventilation. In his letter describing that, published on his return in the 'Times' newspaper, he expressed his conviction that a simple ventilating pump of the kind above referred to would have prevented all the evil. His own death, which happened soon after, was evidently hastened by what he then suffered.

So many of the facts ascertained during the inquiry respecting the epidemic at Croydon, by the Commissioners appointed by Government in 1853, were illustrative of malarial influence, that the medical portion of the final Report is given in the Appendix to this volume.

The great importance of the subject of ventilation, as seen in the preceding narratives, and the little sound knowledge which people in general yet possess respecting it, are the writer's reasons for strengthening here, by one document more, the lesson which he desires to give. Different persons, according to their previous habits of thought and action, apprehend the same truths in different ways and with different degrees of facility, and the writer has felt that, by presenting this subject in several of the aspects in which he has had himself to view it on various occasions, he would increase the chance of his carrying conviction to the minds of many readers. Some persons who may at first think that he has fallen into useless repetition, will probably end by approving of what has been done. This document was sketched on the occasion of the outbreak of Cholera last year (1854). When the Honourable President of the General Board of Health had done the writer the honour to invite him to be a member of his medical council, the substance of the first part of the paper was verbally submitted at a meeting of the Council, and soon after, in November, the written Report, nearly as it is printed here, was sent to the Secretary. The President had deemed it expedient, during inquiry as to the causes and nature of cholera, to request scientific assistance from various special labourers, whose valuable Reports, since rendered, on the meteorology of London, the condition of the public water-supply, as discoverable by chemical and microscopical research, &c., will be read with much interest. And as the attention of the writer of this had been strongly drawn to facts proving the great influence of atmospherical impurities on the course of the epidemic, and the easy possibility in many cases, by new means, of lessening such impurities, he believed that this document would be an acceptable contribution to the mass of information accumulated.

ON ASIATIC CHOLERA AND OTHER DISEASES, AS INFLUENCED BY ATMOSPHERIC IMPURITY.

1. In the year 1817 a destructive pestilence, now called Asiatic Cholera, sprang up near the mouths of the Ganges, and, spreading by human intercourse or otherwise, at last visited almost every country on earth, remaining in any one locality, however, only for a limited time, proportioned generally to the size or population, but repeating its visits after irregular

intervals of years. Because in its modes of attack and diffusion it differed much from other known epidemics, it at first excited unusual consternation; but observation has now clearly ascertained that the travelling morbific cause, whatever it be, can no more produce a true pestilence unless it meet with much filth or impurity of decomposing animal and vegetable matters—of which air which has served for respiration contains one kind—than coal-gas can produce an explosion if not mixed with much common air, or than sulphur can produce the effect of gunpowder if not mixed with certain known proportions of nitre and charcoal. It thus appears that the ravages of cholera may be prevented by preventing local accumulations of organic impurities.

2. To many persons hearing this statement for the first time, the reflection will occur that the laborious researches of medical men and others in regard to cholera, have detected many other things or conditions besides filth which exert powerful influence on the spreading and destructiveness of the disease; but a careful analysis of these particulars shows them all to belong to two classes, of which the one is of things which favour the accumulation of filth, or its decomposition into foul effluvia; and the other is of agents which weaken the living system, and render it more susceptible of harm from filth and other causes. Of the first class are—

1. Whatever gathers filth or impedes its removal, as cesspools and bad drains.
2. Warmth (favouring decomposition).
3. Damp or humidity (with similar effect).
4. Hot and wet seasons.

5. Low river-sides and sea-shores, marshy levels.
6. Seaports.
7. Crowds of people in houses, ships, &c.
8. Enclosed places without ventilation.
9. Calm weather, &c.

Of the second class which weaken the living system are—

1. Intemperance of all kinds.
2. Debauchery.
3. Fatigue of body or mind.
4. Deficient food or long fasting.
5. Bad food, or drink, or air.
6. Depression of mind.
7. Uncomfortable dwellings.
8. Poverty, &c.

None of the particulars of either class, whether singly or in combination, are in this country sufficient to cause cholera unless the epidemic influence which travels be also present.

3. Now, the principal, and in many cases the only, source of the noxious impurities above referred to, is the living body itself, converting into poisonous refuse the whole amount of the animal and vegetable substances which it takes in as food. No portion of these substances is entirely consumed or annihilated, as many people think, but all, after a certain time, is again discharged from the system as excrementitious matter, solid, liquid, or aëriform, and is then pernicious to the health if used a second time; and a fact, by many persons little suspected, is, that a great part of the solid food swallowed passes from the lungs as invisible carbonic acid gas and other exhalation—the

quantity of the solid carbon or charcoal element of food so escaping in twenty-four hours from a healthy man being from eight to twelve ounces. Now even brutes, moved by instinct or annoyance to their senses, fly from, or hide the refuse of their bodies; and men living together in civilized communities, soon have to employ the labour of scavengers, drainage, or other means to remove the more obvious impurities; while the wind, the warmth of the breath, and occasionally artificial ventilation, are removing what is aëriform. In few instances, however, as yet have these means been rendered perfect.

4. The department of the art of cleansing which remains the most imperfect is that of ventilation. The reasons of this are, that air under common circumstances is invisible—that scarcely two hundred years have passed since scientific men began to suspect that air was at all a ponderable space-occupying substance, and only in our own day—since it has been used as stuffing for air-pillows, and one kind with the name of coal-gas has been distributed and sold by measure from pipes, as water is—have people generally conceived of it as being truly a thing; that only about one hundred years ago did chemists learn that air or gas is not a distinct substance of permanent nature, but is one of the three forms called solid, liquid, and aëriform, which certainly most, and probably all, elementary substances may assume under different degrees of heat, compression, and combination; that the particular substance, for instance, to which the name of oxygen was given soon after its discovery by Dr. Priestley in 1783, and which, in its separate state at the temperature of our earth, exists only as an air

that might serve as stuffing for cushions, yet constitutes eight-ninths by weight of all the water on our globe, about a fourth of all the earth and stones, and a large proportion of the flesh and other parts of all animals and vegetables—then men had not until lately reflected that solid or liquid filth in a house, if not swallowed in food or drink, can prove noxious only when it gives out part of its substance as foul effluvium to be breathed; and, lastly, men knew not that expired ordinary breath, which, if inhaled again undiluted when in a recent state may only suffocate by excluding fresh air, becomes, when stagnant or long retained in a place, truly, to a degree, putrid or corrupt, as turtle soup or vension change by keeping, and may then be assuming the form of one of the poisons which produce the jail, the hospital, or the ship fevers, and other spreading diseases; or of that which, when joined with the peculiar morbid agents of smallpox, measles, scarlatina, or cholera, cause these to rage. Acquaintance with such facts, however, being once obtained, men can understand that ventilation is not of ordinary but of paramount importance; for it can remove not only the breath-poison of inmates, but also the foul air arising from all other sources, and so may act as a substitute for good drainage, until there be time and opportunity to establish that. As there is no liquid poison which may not be rendered harmless by copious dilution with fresh water, so there is no aërial poison of which the action may not be similarly weakened by copious dilution with fresh air.

5. It is important also here to remark, that modern houses, since the introduction of close-fitting glass

windows and of chimney-flues with low openings for fire-places, have been rendered what persons ignorant of the nature of air could not suspect, namely—singularly efficacious traps for catching and long retaining all impure air or effluvium which may enter from without, or be produced within them. Such airs, the exhaled breath, for instance, being generally warmer and specifically lighter than the external air, are buoyed up towards the ceiling of rooms, where, if there be no outlet, they stagnate long, like oil floating on water, little disturbed by even copious streams of fresh, colder, and heavier air, gliding along the floor from doors and windows to pass up the chimney-flue. This truth is strikingly confirmed by such facts as the following:—the long time during which tobacco-smoke, smell of dinner, and other odours remain in ordinary rooms—the fact that an ordinary bedroom, occupied by one or more persons, is in the morning to a stranger entering it from the fresh air—a medical man, perhaps called in urgency, always very offensive—that all sick-rooms are usually thus offensive—that a person who, in the early morning before doors and windows have been opened, enters almost any house, under the roof of which modern refinement has placed, without sufficient securities, the foulest receptacle in nature—a closet, with its cesspool and its drains, is forcibly struck by what is called the close, disagreeable smell—the fact that many attacks of cholera have occurred suddenly in the night, and after sound sleep, in such closed houses, to persons who were apparently well when they went to rest; and, lastly, the important fact that the offensive atmosphere in all such cases is almost entirely prevented, or is quickly dissipated, by an open window which admits fresh air to dilute the impurity, or, better still, by having an opening from near the ceiling of the room into the chimney-flue of a well-constructed fire-place, such as is described in the Paper on the 'Smokeless Fire,' lately published in the Journal of the Society of Arts, so that the strong chimney-draught shall act as a constant air-pump, withdrawing impurity from aloft, where it tends to accumulate. It may be observed here, that as a common gas-pipe, leaking into a close room, if undiscovered, soon converts the air of the room into the mixture of one part of gas and ten parts of common air, which in mines is called fire-damp, and is ready to explode at the instant of contact with a lighted candle; so a leak or source of impurity from drains, or crowded inmates in a close or unventilated room during a cholera epidemic, may soon produce there what might be called cholera-damp, ready on some accident to cause the outbreak of cholera disease.

6. Malaria, from impure, wet localities, and effluvium from such filth as cesspools contain, have, in past inquiries, been principally attended to; but there are many facts to show that the impurity of retained and corrupted breath, scarcely heeded in general, has been the chief element of the foul atmosphere which has led to numerous cholera outbreaks. Thus, in England, it has been in public institutions, clean to the eye, not very offensive to the nose, and where the inmates were well fed and well clothed, and otherwise well-cared for under frequent public inspection, but where ventilation was overlooked and defective, that some of the most

shocking scenes of destruction from cholera have occurred. Such was the school at Tooting, of above a thousand parish children, among whom about three hundred cases of cholera suddenly occurred, and killed more than half of those affected before the crowd was dispersed. And various union workhouses, lunatic asylums, prisons, &c., in London and elsewhere, were similarly visited. Such places, in the end of 1849, produced more than half the cases of cholera which then occurred about London, as is set forth at page 37 of the valuable 'Report on Cholera,' prepared by Dr. Baly and Dr. Gull, and issued by the College of Physicians. The very crowded school of the union-house at Taunton, in Somersetshire, became a remarkable example: thirty cases suddenly appeared in the room of the girls, in which the glass of the windows remained entire, while in the adjoining room of the boys, where panes of glass were broken and so admitted fresh air, not a single case occurred, and there was only one other case in the whole town.

7. A large proportion of the facts set forth in the Report on Cholera above referred to, gives strong support to the views here taken, as do also the details of other histories of cholera wherever occurring. The accounts lately received from the allied fleets in the Black Sea have shown that cholera had been much more destructive in the great three-decked ships, in which adequate ventilation was more difficult, than in the ships of smaller size. In India it has been found on several occasions that in encampments where there was scanty accommodation, the putting an additional man into every tent has increased strikingly the prevalence and mortality from cholera; and almost

everywhere during attacks of cholera it has been found that the removal of persons from crowded, unventilated, dwellings, in or about which cesspools or other foul receptacles existed, to tents or any clean shelter on dry, open ground, has at once arrested the spread of the disease.

The remarkable fact that scavengers and nightmen, whose common work is carried on among the most offensive filth, but almost always in the open air, have rarely been affected by the disease, indicates the power of dilution of a poison to render it harmless. Some of these men, however, occasionally, on penetrating into close unventilated drains, have narrowly escaped suffocation, and on coming out have been attacked with violent vomiting and purging. This last-mentioned fact proves how rapidly aërial poison can enter the system to affect the intestinal canal somewhat as happens in cholera. Showing again, that even in the open air there may be concentration of poisonous effluvium sufficiently powerful to operate very hurtfully, Sir John Pringle narrates, in his valuable work on the 'Diseases of the English Army while serving in the Netherlands,' during the middle of the last century, that, in the camps and in warm weather, destructive dysentery broke out among the men whenever they remained so long in one place that the privies became very foul; and that, when fresh troops came to such places, great numbers were affected on the very first days.

8. Such facts as are set forth in the preceding paragraphs prove both the close dependence of men's health and well-being on the maintenance of purity of air within and about their dwellings, and the lamentable

extent to which the object is at present missed in ordinary procedure. The question, therefore, arises whether means can be placed within common reach of so diluting with fresh air, and expelling the copious aërial poisons generated, wherever men live and work, as to render them harmless? and the answer, it is hoped, may be given that such means do exist, and that they are simple and inexpensive.

9. It might have been expected that the scientific men who first discovered the true nature of different airs and their relations to the animal economy, would have been also the first to devise important applications of the knowledge for the preservation of the public health; but it has not happened so. In this field of human exertion, as in many others, the tasks of purely scientific research and of the subsequent applications to art have lain very much with different parties. It was not, for example, the chemist who first showed a jet of coal-gas burning in his laboratory who also first conceived and accomplished the noble feat of lighting up with gas a whole city, so as almost to make night there appear the day. It was not the persons who ages ago observed the expansive force of steam and its sudden collapse again into water when cooled, who thought of turning steam force to profitable use; for it was left to James Watt almost in our own day to devise the present steam-engine, which has quickly spread a new and higher civilization over the earth. Then for many a day was the fact widely known, that a shock of electricity travelled along a wire with the speed of lightning, before Wheatstone and others, who still live among us, had constructed the electric telegraph, which with the speed of lightning can

deliver at any distance, and can even write down or print the words of any message committed to it. And, lastly, it is true that the application of existing scientific knowledge to the effectual ventilation of human dwellings, is an art which has made as yet but small progress among the multitude.

10. To form just conceptions of what complete ventilation is, and of the general nature of the means required to accomplish it, an inquirer has to consider that the ocean of air called the atmosphere, which lies on the surface of the earth, and at the bottom of which men live as aquatic animals live at the bottom of the sea, is about fifty miles high or deep, and that the portion of this which can be contaminated by any process of animal or vegetable life, or by the decomposition of animal or vegetable bodies when dead, does not exceed in depth the fiftieth part of one mile. This comparatively insignificant, lowest stratum or layer, therefore, may be regarded as the home or lurking-place of all epidemic and insalubrious influences; the more exact statement indeed being that these are generally confined to the still much smaller portions of air shut up in houses or other enclosed places. Then the fact is to be kept in mind that the whole mass of atmosphere, at any moment over a city or other place, is always travelling away to leeward, and moving with the speed of the wind, and is carrying with it whatever impurity may ascend into it from below, which impurity is then ultimately resolved into the simple elementary carbon, oxygen, hydrogen, &c., of which all such impurities consist. Man can no more contaminate permanently the deep atmosphere over him by his proceedings at the bottom of it, than he can

contaminate the wide Atlantic sea by his tiny works on its shores. Then he has to learn that, with the same mechanical ease and certainty as he can substitute pure water from any passing tide or river near him for some defiled water close to the shore, he can substitute pure air from the great atmosphere over head for any air about him which has become unfit for his use.

The incidents of the professional life of the writer of this drew his attention early to the sanitary importance of ventilation and the regulation of temperature, and a familiarity with mechanical arrangements, increased while he was composing his 'Elements of Physics,' suggested to him simpler and more effectual methods than previously existed of obtaining, in many cases, the object sought. These methods have been put to the test, some of them extensively, and have been found to realise the expected results.* The chief of these methods, or means, of which part are original and part are modifications of what already existed, are the following five:—

1. A method of increasing very much the force called chimney-draught, and of securing thereby not only the desired purposes in regard to combustion, but also a greatly-improved ventilation of rooms.†

2. A ventilating air-pump of simple and cheap construction, by which, at trifling cost of hand-labour or

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* Since the substance of this Report was submitted to the Medical Council of the General Board of Health, the Council of the Royal Society have awarded to the author, in approbation of his labours, one of their medals.

† Described at pages 11 and 34.

other force, pure air in any desired quantity may be supplied to large enclosed spaces, as public buildings, ships, &c., with the same certainty and regularity as coal-gas is supplied from ordinary gas-works to private houses.*

3. A method by which, in cold climates or seasons, hot foul air of any sort, while being discharged or pumped away from an enclosed space, is made to give up as pure warmth, to the fresh air entering in its stead, nearly the whole excess of its temperature—and thus, by one operation, are accomplished both the objects of warming and ventilating.†

4. The causing a fire in an enclosed stove, by means of a self-regulating apparatus, to burn with such uniformity that the heat obtainable from the fuel consumed is given out as uniformly as the light obtainable from wax or oil is given out by a candle or lamp; the enclosed fire being further made to burn without interruption through nights and days for any length of time, with scarcely more superintendence than is required for a lamp.‡

5. A new arrangement of the open fire-place, by which a fire of common coal can be rendered always smokeless; and while warming a room better than the ordinary fire, is effecting a saving of from a third to a half of the fuel, and is producing complete ventilation.§

These particulars are here enumerated, not to prove merit in the writer, but to direct public attention to departments of sanitary art in which much improve-

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* Described at pp. 162-3, and 167.

† Ibid. p. 177.

‡ Ibid. pp. 138 and 149.

§ Ibid. p. 7.

ment was wanted. The writer attributes much of his success to favouring accidents in his life, such as other members of the profession, if similarly circumstanced, might have turned to equally good account. The name of Dr. Jenner would not probably have become connected with vaccination if he had resided always in the midst of a great city, far from fields and cows and dairy-servants.

It remains to be observed here that even after good practical applications of scientific principles have been devised, and their utility has been tested to the satisfaction of competent judges, there is often for a time difficulty to induce the public to consider and adopt them. To feel the truth of this, one has only to recall the ridicule at first, and then the more active resistance, with which the announcement of almost all the great modern improvements in the arts of life was originally received—as in the cases, for instance, of agricultural implements worked by steam, of steam machinery for spinning and weaving, of gas-lighting, railways, steam navigation, the penny postage, and so forth. Against all such new proposals were quickly arrayed in action—the attachment of people to the established custom of past times, popular ignorance of nature's laws, strong misconceptions or prejudices, directly opposed to nature's laws, the narrow accidental interests in old things of individuals or classes. And if, in the first trials of a novelty, any failure occurred from the awkwardness or unskilfulness of workmen employed about what was new to them, or from other cause, the fault was sure to be held up by opponents as proof of error in the principle. In cases when at last, notwithstanding such opposition, a novelty was proved to be good, then, almost as certainly as flies collect about a little honey dropped on a table, did a host of dishonest men for selfish purposes assail the proposal and the proposer—asserting that the proposal had not such novelty in it as could be secured by patent, although some modification proposed by themselves, the objectors, might be so secured. By such opposition as this, the full introduction of Watt's steam-engine was retarded for many years, and the inventor had to defend his patent rights by repeated appeals to Courts of Justice. But, sometimes, even enlightened and upright men have been slower than might have been expected to acknowledge the merit in new inventions, partly from caution, taught them by seeing the mass of crudities and absurdities constantly pressed on public attention as improvements, by ignorant or foolish projectors, and partly because sufficient evidence of the worth of the new proposal was not yet before them. For instance, such distinguished scientific men as Davy, Wollaston, and Watt, at first gave an opinion that coal-gas could never be safely applied to the purpose of street-lighting. Others said that steam-ships would never be able safely to navigate the great ocean. When Dr. Desaguliers and Dr. Hales, about a century ago, before oxygen was known, or the nature of gases generally was understood, still judged aright of the importance of pure air to health and life, and proposed to ventilate houses or ships by mechanical means of certain or unfailing action, instead of by the agency of the inconstant wind entering windows, ports, or wind-sails, they were regarded by some honest persons in authority as erring visionaries. A curious fact belonging to this class of occurrences, and recorded by writers of the time, was that after Dr. Harvey published his great discovery of the circulation of the blood, no medical man who had then reached the age of forty, ever avowed his belief that Harvey was right.

Considering such facts, the writer of this Report, who has not taxed the adoption of his devices by reserving any patent right or pecuniary interest in them, is of opinion that time will be saved and public good will be effected, if the Honourable President of the General Board of Health now cause to be nominated a commission of a few men, representing medical, chemical, and engineering science, and of known ability in relation to the matters here treated of, to examine what has been done and to report thereon. The writer will be happy to give his assistance in bringing the subjects completely before them. Special scientific aid has already been afforded to the medical council of the General Board of Health for other specific objects. The award of the Royal Society above referred to will draw some public attention to the subject; the writer's own account of them, now in the press, will also have its effect; but a report and recommendations from such a commission as referred to, if favourable to the measures proposed, would have at once almost the influence of a law in securing attention everywhere, and willing obedience to any advice given.

November, 1854.

PART THIRD.

ON WARMING IN GENERAL.

Heat is that something which makes the difference between summer and winter, and which when present in a body touched by the hand is said to make it feel hot, and when absent to make it feel cold,—but it cannot be exhibited apart, and is known to be present in bodies chiefly by its effects on them, as of expansion, melting, &c. The change of its quantity in a body is conveniently estimated by the accompanying expansion or change of bulk; and any substance so placed as to let that change be accurately measured constitutes a *Thermometer*. Heat diffuses itself among neighbouring bodies, so that all have soon the same temperature, that is, they all similarly affect a thermometer. It spreads partly by radiation like light and partly by conduction from any particles to neighbouring touching particles. The great source of heat to this earth is the sun; but fire or the act of combustion and other chemical actions produce it in smaller quantities.

All animal bodies require to have in them a certain temperature, differing in degree for different kinds, which in those called warm-blooded, is considerably higher than that of the surrounding atmosphere; and by the actions of life they maintain in themselves that which to each is suitable. This continues very nearly uniform, notwithstanding considerable fluctuations in temperature of the air and of other objects around them. In man the animal heat is of 98° of Fahrenheit, whether under the burning sun of India, or amidst the snows of the pole. The animal heat is maintained above lower surrounding temperatures chiefly by the function of respiration, in which the oxygen of the air, received into the lungs, combines by a kind of slow combustion with carbon from the blood, and gives out heat, nearly as when oxygen and carbon combine in a common fire. This focus of heat suffices to maintain the healthy temperature even in a naked body, in air at from 60° to 70°, which absorbs much heat from the surface; and in bodies clothed with fur or feathers, it will maintain that temperature in air which is very cold indeed. When, on the other hand, the temperature around animals is high, the body relieves itself of its superabundant heat, chiefly by increased perspiration and evaporation from the skin and lungs. To fit the inferior warm-blooded animals for the various climates of the earth, different qualities and thicknesses of hair or feathers are given to them; but man, who visits all climates, is left to use his reason, and to clothe himself according to the existing necessity; or, with less clothing, he may in any situation employ fire to make the air of his dwelling of the temperature which suits the kind of clothing which he permanently prefers. In China men prefer to secure themselves against the severe winter colds, chiefly as inferior polar animals are secured, viz., by thick clothing. In Europe they generally prefer to wear in the house more nearly their summer dress, while by fires they artificially warm the air to nearly summer temperature. The safer plan of the two for unskilful persons, is perhaps that adopted in China, because the defence is as constant and uniform as the season which demands it. And that the human frame, if well clothed, is fitted to breathe, even with delight as well as safety, a very cold air, is proved by the feelings of persons in a warm bed, during a winter morning cold enough to freeze water which is standing in the room; or, by the feelings under a clear, but intensely cold winter sky, of children at play, skaiters on the ice, or sportsmen in the field. It would be a good rule for persons in Europe to clothe themselves in winter so as to be comfortable in a room at a temperature of 60° or 62°, and to let that be the steady temperature of their common apartments, which then would never be dangerous either to enter or to leave. Now, with common fires in England, rooms are often heated up to 70° or above, and are often cooled down to 50° and below.

While *natural warmth* then, in relation to an animal body, is that generated in the body itself, and retained in it sufficiently by the natural covering counteracting the temperature of the climate; *artificial warmth* is the maintenance or modification of the natural, produced by artificial covering called clothing and lodging, and by the agency of combustion or fire. The phrase popularly refers to the action of fire; and we now proceed to describe the nature of fire, and to examine the successive steps by which men have sought to derive the greatest advantage from it.

Fire or ordinary combustion is chemical union taking place with intense energy, productive of light and heat, between the oxygen of the atmospheric air and some substance to which oxygen has strong chemical attraction. The substances which so combine with oxygen are called combustible, and of these the most common and cheapest are coal, wood, coke, charcoal, and peat. A quantity of any of these substances heated to redness or ignition, and placed where a current or change of air can reach it, immediately begins to combine with the oxygen and to be dissolved therein and dissipated, with appearance of flame or light, and with powerful generation and dispersion of heat,—in a word, it is said to burn. In this process constant renewal of fresh air is required, just as for animal respiration, and is furnished by nature nearly in a similar way, the air heated and expanded by contact with the burning fuel quickly and continually ascending to be replaced by fresh air.—Of the heat produced in the combustion of coals, a proportion rather more than half is radiated around the fire, as the light is from a fire or from a candle, and rather less than half combines with the air which feeds the combustion and rises with the smoke, to be dissipated in the atmosphere. Experiment has shown, that the combustion of

One pound of good	Coal	Melts of ice . .	90 lbs.
—	Coke	— . .	84 —
—	Wood	— . .	32 —
—	Charcoal of wood . .	— . .	95 —
—	Peat	— . .	19 —

indicating the comparative values of these substances as fuel:—and the exact relation is known between the quantity of heat required to melt a certain weight of ice, and to effect any other results. For instance, the quantity of heat which raises the temperature of a cubic foot of water one degree, being considered a standard of comparison and called *one*, of such *ones* or units, 140 will melt a cubic foot of ice; 180 will raise the temperature of a cubic foot of water from 32°, or freezing, to 212°, or boiling temperature; 960 more will convert that into steam; and what heats a cubic foot of water 1°, will heat 2850 cubic feet of common air also 1°, or will heat half that quantity 2°, and so forth. One mode of estimating how much of the heat of a fire radiates around it, and how much combines with the smoke, is to let all the radiant heat melt ice in a vessel surrounding the fire, and all the heat of the smoke melt ice in another vessel surrounding the chimney. Progressive steps in the art of warming are the following: —

A Fire in the open Air.

The first step made by man in the art of warming himself by fire would naturally be, simply to light a fire in some convenient situation in the open air, and to place himself near it. In so doing he would benefit only by a portion of the radiant heat, namely that which fell on, or was intercepted by, his body; while the rest of the radiant heat, and the whole of the heat combined with the smoke, would be lost, or dissipated in the atmosphere. Houseless savages still use fire in this way, as do soldiers in their bivouacs.

A Fire under Cover.

A second step would be to light the fire in a place more or less sheltered or enclosed. Then, not only would the part of the radiant heat which impinged directly on the bodies of persons present be rendered serviceable, but of the remainder also, what fell on the walls and warmed them, would be partially reflected to the bodies within; and moreover, the heat combined with the smoke would be for a time retained in the place, and would still further warm the walls and roof, and the inmates. By such an arrangement, nearly the whole of the heat evolved in the combustion is for a time applied to use; but it is conjoined with the smoke, or offensive vaporized products of the fuel, for which some issue must be provided. The savages of North America thus place fires in the middle of the floor of their huts, and sit around in the smoke, for which there is escape only by the one opening in the hut which serves as chimney, window, and door. Some of the peasantry in remote parts of Ireland and Scotland still place their fires in the middle of their floors, and for the escape of the smoke, leave only a small opening in the roof, often not directly over the fire. In Italy and Spain almost the only fires seen in sitting-rooms are large dishes of live charcoal, or braziers, placed in the middle, with the inmates sitting around, and having to breathe the noxious carbonic acid gas which ascends from the fire and mixes with the air of the room. There being no chimney, the ventilation of the room is imperfectly accomplished by the windows and doors. The difference between the burned air from a charcoal fire, and the smoke from a fire of coal or wood is, that in the latter there are added to the chief ingredient, carbonic acid, which is little perceived, others which disagreeably affect the eyes and nose, and so force attention. Within a few years the barbarous mode of warming here described was used in the halls of some of the London Inns of Court, and of colleges at the old English Universities.

The open Fire under a Chimney.

A third step of advance in the use of fuel was to construct over the fire, a flue, or chimney, which should receive all the smoke or offensive aëriform matter rising from a fire, and by gathering it into a long light column of air, should cause it to rise like oil in water with what is called a strong draught, and so depart to mix above with the passing wind. This is the plan now generally used in England, and we shall therefore take the common open English fire as a familiar standard with which to compare other plans; and we shall moreover consider all the plans in reference to the great object sought by them, of obtaining everywhere on earth, at will, the temperature most congenial to the human constitution, and an air as pure as blows on a hill-top.

By an *open English fire* it is possible to obtain in a room any desired temperature. The heat used, however, is that portion only which radiates around with the light, while all that combines with the smoke passes up the chimney. This radiated heat first warms the walls and other objects on which it falls, as described in the observations on low fires at page 25, and these by contact with the air of the room then warm it. But there are weighty disadvantages which we shall now enumerate, all of which, however, can in a great degree be remedied by such arrangements as constitute the smokeless fire, described in the first chapter of this work.

I. *Waste of Fuel.*—Of the whole heat produced from the fuel used in many common fires, about seven-eighths ascend the chimney, and are absolutely wasted. This loss of heat consists, first, in the more than half which is in the smoke as it issues from the burning mass; secondly, in that carried off by the current of the warmed air of the room, which is constantly entering the chimney between the fire and the mantel-piece and mixing with the smoke: this is estimated at about a fourth; thirdly, in the fact that the black or visible part of the smoke of a common fire is really a precious part of the coal or wood escaping unburned. If then more than half of the heat produced be in the smoke, and nearly a fourth of it in the warm air from the room which escapes with the smoke, and if about an eighth of the combustible pass away unburned, there is a loss of seven-eighths of the whole. Count Rumford estimated the loss as being in many instances still greater. It was he who had the great merit of first explaining well how, by contraction of the chimney-throat, much of the waste might be saved, and other advantages secured.

II. *Unequal Heating at different Distances from the Fire.*—The intensity of radiating heat, like that of radiating light, is not, as many would expect, one-half as great at a double distance, but only one-fourth, and at triple distance is not one-third, but only one-ninth, and so on in all cases, being inversely as the square of the distance. This distribution of heat in a room forms a remarkable contrast with the uniform temperature in the air of a summer apartment. In rooms with a strong fire, in very cold weather, it is not uncommon for persons to be scorched on one side, and chilly or half-frozen on the other. This is true particularly of large apartments ; for the distant walls are little warmed, and therefore reflect little heat to the backs of persons around the fire. In large apartments with open fire, there is ordinarily one circular line around the fire on which persons must sit to be comfortable ; within which line they are too hot, and beyond which they are too cold.—It is remarkable how few persons in society understand the singular power of screens standing in rooms to increase and equalize the warmth to persons sitting between them and the fire. The common notion is that they merely ward off the draughts of cold air moving towards the fire from doors and windows. This they certainly do ; but, what is more important, they intercept on the other side, and catch great part of the heat radiating from the fire, and being themselves thereby much warmed they reflect heat on the backs of persons sitting within them, and really comfort them as a shawl or greatcoat would. They also prevent the distant cold windows and walls from absorbing heat radiated from the warm bodies of the inmates.

III. *Cold Draughts.*—Air being constantly wanted to feed the fire, and to supply the chimney-draught above described, the fresh air, entering by doors and windows, is felt often most injuriously, as cold currents. Such currents become very remarkable when doors or windows are opened, for the wide chimney can take much more than it receives when the doors and windows are shut. Then for the time the room with its chimney is like an open funnel, rapidly discharging its valuable contents.

IV. *Cold Foot-bath.*—The fresh air which enters in any case to supply the fire, being colder and specifically heavier than the general mass already in the room, lies at the bottom of this as a distinct layer or stratum, demonstrable by thermometers, and forming a dangerous cold bath for the feet of the inmates, often compelling delicate persons to keep their feet raised out of it by foot-stools, or to use unusual covering to protect them.

V. *Bad Ventilation.*—Notwithstanding the rapid change of air in the room, perfect ventilation of the whole is not effected. The breath of inmates does not tend towards the chimney, but directly to the ceiling, and as it must therefore again descend to come below the level of the mantel-piece ere it reach the chimney, the same air may be breathed again and again. In a crowded room, although with an open fire, the air is for this reason often highly impure. As another source of impure air in a house, it is to be noticed, that the demand of the chimneys, if not fully supplied by pure air from about the windows and doors, operates through any other apertures, and thus often brings in foul air from drains, &c.

VI. *Smoke and Dust* are often unavoidable from an open chimney, much affecting the comfort and health of the inhabitants of the house, and destroying the furniture. Householders would make great sacrifices to be free from the annoyance of smoke. In large mansions, with many fires lighted, if the doors and windows fit closely, and sufficiency of air for so many chimneys cannot therefore enter by them, not only do the unused chimneys become entrances for new cold air, but often the longest and most heated of the chimneys in use, overpower the shorter and less heated, in which also there are fires—in the same way as the long leg of a syphon overpowers the shorter leg—and cause the shorter chimneys to discharge their smoke into the rooms.

VII. *Loss of Time.*—During the time every morning while the fires are being lighted, the rooms cannot be used; and there is, besides, much annoyance from smells, smoke, dust, and noise. When neglect of servants lets the fire go out in the course of the day, it has to be lighted again.

VIII. *Danger to Property.*—In London alone, there are on an average more than 100 fires per month.

IX. *Danger to Person.*—Often in houses burned, some of the inmates perish. The newspapers of one day sometimes report three or four cases of children burned to death, by being left with access to fires or candles. It is not an uncommon accident for a lady, happening to stand or pass near the fire at a moment when the door is opened, to have her thin dress wafted towards the fire by the sudden draught from the door, and so set in a blaze.

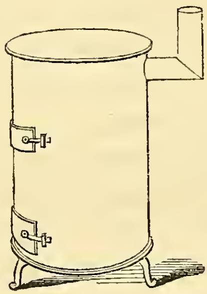
X. *Expense of Attendance.*—To light the fire in the morning, and to keep it alight with tolerable uniformity during the day, the frequent attendance and labour of a servant is required—much increasing the expense of the fire.

By contrasting the disadvantages here enumerated of the common open fire with the performance of the smokeless open fire described in the first chapter, it will be seen how all these disadvantages may be much lessened or entirely avoided.

The common Close Stove.

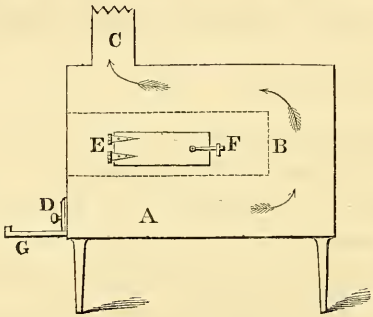
In northern continental Europe generally, where fuel is not so abundant and cheap as in England, but where the winter cold is more severe, the common open fire above described, wasting at least three-fourths of the heat produced, would be much too expensive; and, in fact, could not be made at all to answer the purpose intended. Hence another plan has been adopted, called the *close stove.*

Fig. 5.



In the form here exhibited, for instance, which is commonly known as the Dutch stove, the fuel rests on the bars of a grate near the bottom, the air enters below the grate to feed the combustion; fuel is introduced by a door above the grate, which door is closed while the stove is in action, and as it is the only opening above the fire, no air can reach the chimney, but what has fed the combustion. Now this stove saves all the waste of warm air, which, in open fires, passes between the fire and the mantel-piece, while by the surface of its body and flue receiving and giving to the room not only the direct heat of the combustion, but also of the intensely-heated smoke rising from the fire, it utilises much of the heat, which, in a common open fire, would at once pass away by the chimney. Indeed, if the flue of the stove be made very long, so as to expose in the room a great surface for giving out heat, nearly the whole heat of the combustion may be applied to use while all the smoke is carried away. Then, in a room so heated, there are neither draughts, smoke, nor dust. By such a stove, therefore, several of the disadvantages of the open fire are completely obviated. There is, however, one disadvantage peculiar to the close stove, which countervails nearly all its good qualities, namely, that its very heated surface of iron acts upon the air which comes in contact with it, so as to impair exceedingly the purity and fitness for respiration. The air acquires a burnt and often sulphurous smell, in part, no doubt, because dust, which it often carries, is burned, and in part because there is a peculiar action of the iron upon the air. It becomes very dry, too, like that of an African simoom, shrivelling everything which it touches; and it acquires probably some new electrical properties. These changes combined, make it so offensive, that Englishmen unaccustomed to it, bear it ill. In this country many forms have been proposed, some of them gracefully designed, with transparent talc doors and other attractions; and they have been tried in rooms, public offices, passages, halls, &c., but have been afterwards very generally abandoned. Persons breathing the air heated by them are often affected by headaches, giddiness, stupor, loss of appetite, ophthalmia, &c. A north-east wind, which distresses many people, bringing asthmas, croups, &c., and which withers vegetation, is peculiar chiefly in being dry. The stove above described is much employed in this country by laundresses and others for drying, and in that use it is good and economical.—A very common fire-place, in the United States of North America, is a square close iron stove, such as is here

Fig. 6.



sketched in section, with a vessel of water upon it to give moisture to the air. The stove has a hearth-plate G projecting under the door D; the wood fuel is burned within at A, and the flame passes along by B, to the chimney C, around an inner box E F, which is the cooking oven of the family, opening by a door E in the side of the stove. The fuel is introduced by a large door at D, in which there is a smaller door, which as well as the larger is usually kept shut, because enough air can enter by the joinings around, but in cold weather the small door is opened, to increase the combustion. The stove has iron legs, of about a foot long.

In northern continental Europe, to avoid deteriorating the air by the overheating of the surface of an iron stove, it is now common to make close stoves and their chimneys of thick brick-work, either included in the walls, or projecting as a bulky mass into the rooms, the mass being often covered with porcelain. These do not allow the heat of the fire to pass outwards so quickly as a metal stove, and hence their exterior does not become so much heated. In many cases, to prevent waste of the warm air from the room, and to avoid the frequent entrance of attendants, the stove is not fed with air from the room itself, but through the wall behind from a passage near, or from the external air. Such massive stoves are charged with fuel, and lighted, in general, only once in the day; and after the combustion has continued long enough to drive off all the evaporable matter from the fuel of wood or coal, the chimney is nearly closed, and the remaining ignited charcoal or coke is allowed slowly to give out its heat and to consume. The heated mass of the stove continues to warm the room long after the fire is extinguished, but of course with diminishing power. These stoves, as compared with an open fire, are very economical. An English gentleman once at St. Petersburg, wishing to see there his old English fire, had additionally an open chimney constructed, but found that with all it could do, and although the close stove also was plied as much as possible, and was lighted twice in the day instead of once, the room was much colder than before.

An economical mode, formerly used by the Romans, and still seen in China, of using fuel to warm rooms, is to have the floors made of thick tiles, below which the hot smoke of an enclosed fire passes.

In a future section will be described a self-regulating close stove, which completely avoids the disadvantages of the Dutch and other continental close stoves above described.

In England, where such activity of thought has of late prevailed on most subjects interesting to humanity, and where, from the advancement of the arts generally, new wants in relation to temperature arose, which scarcely existed elsewhere—as in the necessity of keeping at a steady temperature factory rooms so large, that one fire was insufficient, and more than one were inadmissible,—the imperfection of the open fire, and of any known close stoves, having been strongly felt, other means were eagerly sought, and are now extensively used; namely, 1. Steam admitted to spread in pipes or other vessels placed in the apartments to be warmed; 2. Hot water similarly admitted and distributed, and circulating back to the boiler to be heated again; and, 3. Heated air prepared in a separate place, and then distributed by various means over the building.

Of Heating by Steam.

Steam admitted into any vessel not so hot as itself, is rapidly condensed into water, and at the same time gives its heat to the vessel, which then diffuses the heat in the space around. It is found that if a boiler for heating a house by steam be carefully set, like that of a steam-engine, on a close furnace or fire-place, which admits no more air than is required to support the combustion, and keeps the hot air or smoke in contact with the sides of the boiler, until as much as may be of the heat is taken from it, such a boiler turns to use more than half of all the heat produced in the combustion, instead of the one-eighth of the old open fire. The other advantages are, the power of distributing the heat as may be desired, there being no dust or smoke in the room, no draughts, no cold air on the floor, no danger of fire in the place warmed, and that when there are many rooms, or a large establishment to be warmed from one boiler, less labour of attendance is needed. This mode of heating is found highly advantageous in the extensive manufactories, where steam-engines and boilers are already established for other purposes. In the cotton factories, accordingly, where the quality of the thread preparing may be injured by even a small change of temperature, steam is almost universally used; and where a good system of ventilation is added, the air of the establishment is at all times temperate and pure, and the best effects have been produced on the health of the workpeople.

The objections to steam-heating, for smaller establishments, are the great expense of constructing and placing the apparatus; consisting of boiler, fire-place, safety-valves, feeding-pipes, distributing-pipes, &c. &c.; then the danger of explosion; the chance of the apparatus falling out of order, and the difficulty of getting servants to manage it well and safely; the time to wait after lighting the fire before the apparatus acts; and that it can scarcely be used at a lower temperature than 212°, for the steam ceases to enter it when the water ceases to boil; and even if the boiling be not sufficiently active, the distant parts of the pipes will receive no steam, and will become cold.

To determine the extent of surface of steam-pipe or vessel necessary to warm particular apartments, it was to be considered that the loss of heat from the apartments occurs in three ways: 1st, rapidly through the thin glass of the windows; 2dly, more slowly through the thick substance of the walls, floor, and ceiling; and, 3dly, in combination with the air which escapes at the joinings of the windows and doors, or at other openings purposely made for ventilation. Different writers and manufacturers have made very different estimates of the quantities of heat lost in these various ways, and as yet no popular exposition of the matters has been made with the accuracy which the subject deserves; but an intermediate estimate, as applied to common cases, may be shortly stated thus:—that in a winter day, with the external temperature at 10° below freezing, to maintain in an ordinary apartment the agreeable and healthful temperature of 60°, there must be of surface of steam-pipe, or other steam-vessel, heated to 200°, (which is the average surface-temperature of vessels filled with steam of 212°,) about one foot square for every six feet of single glass window, of usual thickness; as much for every 120 feet of wall, roof and ceiling, of ordinary material and thickness; and as much for every six cubic feet of hot air escaping per minute as ventilation, and replaced by cold air. A window, with the usual accuracy of fitting, is found to allow about eight feet of air to pass by it in a minute, in obedience to a chimney-draught, and there should be for ventilation at least four feet of air a minute for each person in the room. According to this view, the quantity of steam-pipe or vessel needed, under the temperatures supposed, for a room sixteen feet square by twelve feet high, with two windows, each seven feet by three, and with ventilation by them or otherwise at the rate of sixteen cubic feet per minute, would be—

For 42 Square feet of glass	(requiring 1 foot for 6)....	7
1,238 Feet of wall, floor and ceiling....	(requiring 1 foot for 120)....	$10\frac{1}{3}$
16 Feet per minute, ventilation....	(requiring 1 foot for 6)....	$2\frac{2}{3}$
	Total of heating surface required	20

which is, twenty feet of pipe four inches in diameter, or any other vessel having the same extent of surface, —as a box two feet high, with square top and bottom of about eighteen inches. It may be noticed that nearly the same quantity of heated surface would suffice for a larger room, provided the quantity of window-glass and of the ventilation were not greater; for the extent of wall owing to its slow-conducting quality produces comparatively little effect.

An elaborate exposition of the laws of transference of heat is contained in Leslie's Essay, in Tredgold's able Treatise on Warming, written when steam was deemed the generally preferable means of effecting the object, in Mr. Hood's able book on Warming by Hot Water, and in various reports of accurate courses of experiment on the subjects. To these the reader is referred for fuller information; but to give an idea of the mode of dealing with the subject, the following short explanation is added.

A heated surface, as of iron, glass, &c., in a room, gives out heat with rapidity nearly proportioned to the excess of its temperature above that of the air around it and the rapidity of any motion produced in the air,—less than half the heat being given out by radiation, and more than half by the contact of the air. Thus one foot of iron pipe of 200° external temperature in the air of a room at 60°, the difference between them or excess being therefore 140°, gives out nearly seven times as much heat in a minute as when its temperature falls to 80°, reducing the excess to 20°, or a seventh of what it was. If window-glass, therefore, cooled at the same rate as iron plate, one foot of the steam-pipe iron in a room would give out as much heat as would be dissipated from the room into the external air by about five feet of window, the outer surface of which were 30° warmer than that air. But, because glass both conducts and radiates heat in any case slower than iron, the external surface of glass of ordinary thickness, forming the window of a room heated to 60°, would, in an atmosphere of 22°, be under 50°, leaving therefore an excess of less than 30°; and about six feet of glass would be required to dissipate the heat given out by one foot of the iron steam-pipe. Through very thick panes of glass, or through double windows of thin glass, whether consisting of two sashes, or of double panes half an inch apart in the same sash, the loss of heat is only about a fourth part of what takes place through a single ordinary window. Then, it is a fact ascertained by experiment, that one foot of black or brown iron surface, the iron being of moderate thickness, with 140° excess of temperature, cools in one second of time

156 cubic inches of water, one degree of Fahrenheit's thermometer. From this standard fact, and the law given above, a rough calculation may be made for any other combination of time, surface, excess, and quantity. And it is to be recollected that the quantity of heat which changes in any degree the temperature of a cubic foot of water produces the same change on 2,850 cubic feet of atmospheric air.

Warming by Hot Water.

Of this process there are two very distinct forms or modifications, dependent on the temperatures of the water. In the first, water is used at or below the ordinary boiling temperature, and where the pipes do not rise much above the level of the boiler, the vessels need be of no unusual strength. In the second, the water is heated often to beyond 300°, and is seeking, therefore, to burst out as steam, with a force of seventy pounds or more on the square inch, and can be confined only by very strong, or high-pressure apparatus.

For the first modification is required an ordinary boiler, from near the top of which a tube rises to traverse the place or places to be warmed, and then returns to terminate near the bottom of the boiler. Along this tube the heated water circulates, giving out its heat as it proceeds. If the boiler be open to the air, the tube, when once filled with water, acts as a syphon, having an ascending current of hot water in the shorter leg, and a descending current of the cooled water in the longer; the rapidity of motion in all cases depending on the difference in the perpendicular heights of column, and in the temperatures, or specific gravities of the two currents. If the boiler be closed, except through the tubes, the syphon-action disappears, and the boiler with the tubes becomes as one vessel; but still the circulation proceeds as in the other case.

This mode of heating, in many respects, resembles that by steam, but there are differences. Advantages are, that for some situations it costs less; that with the open boiler there is no danger of explosion; that whereas steam does not rise into ordinary pipes until the water producing it has attained the boiling temperature, in this, the circulating water may be of any temperature above that of surrounding objects, and will have motion beginning as soon as the fire is lighted, and not ceasing until the water becomes again quite cold, that the great mass of water heated, lessens the chance of fluctuations of temperature in the place. On these accounts hot water, as a heat-distributor, has lately been preferred to steam in many hot-houses, conservatories, private-dwellings, schools, public offices, &c.* Disadvantages of the water-circulation at low temperature are, the great bulk and expense of the apparatus, the slowness of the motion where the height of columns is small, the chance, if the fire be not lighted, of the water freezing and bursting the pipes, and the long time required to heat or cool the mass of water employed.

The other, or high-pressure form of hot-water apparatus proposed by Mr. Perkins, consists in a great length (it may be 1,000 feet or more) of very strong iron pipe, of from one to two inches in diameter,

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* See Hood's able 'Treatise on Warming by Hot Water.'

formed into a circuit, in which the water endlessly runs round. Such tube, from its smallness and flexibility, is easily laid along to fit any form and succession of rooms and passages, and is gathered into a heap or coil in the various situations where much surface is required, whether for giving out heat, as in rooms and staircases, or for receiving it, as around the burning fuel. It thus requires neither radiating vessel nor boiler, other than portions of itself, and is therefore beautifully simple; but from the great strength and thickness required in the whole length of the pipe, with safety-valves, feeding-contrivance, peculiar joinings, &c., of corresponding strength, it becomes an expensive apparatus. It is liable to bursting, although the accident is not of such importance as when a capacious boiler explodes; its high temperature often gives smell, or other disagreeable quality to the air around, and it may heat dangerously any wood or other combustible matter near. The circulation in it is very rapid, owing to the water, on leaving the fire-place, being generally mixed with steam, and therefore being as a mass specifically light.

By using, with the forms of steam and hot-water apparatus now described, the self-regulating fire treated of in a subsequent part of this essay, many of the objections to such apparatus are avoided, and new advantages are obtained.

Hot-Air Distribution.

For this plan of warming when first introduced, the air was usually prepared by being sent through pipes or other channels connected with furnaces, fire-grates, stoves and their flues, cockles, &c., and being generally much overheated, it required copious dilution with cold fresh air before it could be breathed. By the overheating, it was generally vitiated, as described at page 119, under the head of the "Close Stove," and in many cases it affected so hurtfully the health of inmates, as at once to draw attention to the subject. Very heated air entering a room by one opening, does not diffuse itself readily in the air already present, but, like oil in water, rises at once as a distinct mass or current to the ceiling, and may then soon be lost, by passing away unmixed in the ventilation. When the attempt has been made to distribute air heated in one place through various rooms, at different distances and on different levels, by the mere influence of the comparative levity of the heated air, there has generally been signal failure, owing to the disturbing influences of difference of altitude in the conduit pipes or columns, and of difference in the action of the chimneys, windows, and doors in the various rooms. It will be seen in the following pages, however, that it is possible to warm air by apparatus containing hot water or steam, or by other means, to a temperature always moderate, and then, by unfailing mechanical agency, to distribute it through any building, in whatever manner may be desired.

PART FOURTH.

THE SELF-REGULATING FIRE.

The preceding paragraphs contain a sketch of the chief means of warming which were known and practised up to the year 1834. Various professional occurrences about that time called the attention of the writer of this, to the important art of controlling temperature in our dwellings, for the purposes of health and comfort. The subject had before engaged his thoughts, enough to make him aware that there were many errors of common practice easily avoidable, and to give him an impression that a revision of it might lead to new and useful results, one of which might be "to be able to secure effectually, in any part of the world, and at all seasons, the temperature, moisture, and purity of atmosphere most congenial to the human constitution." That he might have constant motive and better opportunity to observe, to experiment, and to reflect on the subject, he directed a manufacturer to fit up in his library, the apparatus for warming by circulating hot water. Accordingly a box of iron to hold water was placed at one side of the room, having communication by ascending and descending pipes, with a boiler fixed at the back of the kitchen fire, and so that as soon as the fire was lighted, circulation of the water might commence, and be continued at nearly boiling heat while the fire burned. This apparatus effected, in weather not very cold (for the box chosen for him was of too small dimensions for the room), the pleasing results described in a former page, as belonging to the warm-water circulation—mild, equal temperature over the room, no dust, smoke, trouble of watching a fire, danger of fire, draughts, cold layer of air on the floor, &c.; but there were many objections.

In a general review of the subject, the writer was particularly impressed with the great want, or desideratum, then existing, of an arrangement of fire-place, which should do for coal, nearly what the beautiful devices of the candle-form and of the lamp do for wax, and oil—that is to say, a fire-place, by which a considerable quantity of fuel, after being lighted, should be caused, without farther interference of an attendant, to give out all the heat producible from it, as uniformly at any desired rate, as a candle causes a quantity of grease or wax to give out its light, or as a lamp does the same in regard to a quantity of oil. Even an approach to uniform combustion in a common fire, cannot be obtained without careful watching and frequent interference of an attendant to supply fresh fuel, to stir and arrange the fuel so as to favour the currents of air needed to support the combustion, and to do other services which often demand considerable skill. The object sought he soon saw was attainable in two ways: either by admitting to the fuel burning in an enclosed space a nearly uniform stream of air to support the combustion, or by connecting with the air-entrance to an enclosed fire a Thermometric Regulator, adjustable to any temperature, and which should afterwards narrow or diminish the air-entrance, if the temperature of the stove began to increase, and should widen or enlarge it, if the temperature began to diminish, so as quickly to restore the middle temperature wanted.

The first way mentioned is to govern the combustion by rendering the stream of air which enters the stove, in obedience to what is called the chimney-draught, uniform in amount. The nature of chimney-draught was explained at page 38, and its strength may be judged of by holding a sheet of paper, or a spread handkerchief, before an acting chimney-mouth and observing how the obstacle is forced inwards; or by holding a burning candle near an opening into the ashpit of a close stove, and observing how the flame bends towards the opening. It is this force which causes the smoke of an ordinary fire to ascend the chimney-flue, and which impels through the fire, in a grate or stove, the fresh air which supports the combustion.

Persons might at first suppose, that by having a simple opening into the ashpit of a close stove, with a slide-cover moveable by hand, to make the opening larger or smaller at will, the stove charged with fuel, and having the air-entrance opened to a given extent, would burn its fuel as uniformly as a lamp burns its oil; but the fact is much otherwise, for the force of a chimney-draught is influenced by—change of the wind, by the temperature of the outer or inner air, by the opening and shutting of doors, by the force of the fire, &c.; and thus it varies so much, that the same opening may at one time be admitting air enough greatly to overheat the stove, producing the evils described at page 119, and at another time not enough to keep the fire alight. A valve or air-door therefore was wanted, which should be ever changing the size of the opening, so as to neutralise the effect of changes in the force of the chimney-draught. Such is the *Balanced Regulator*, to be described below, the nature of which will, however, be more easily understood by considering, first, the action of the very simple but less perfect *Pendulum Valve*, which among other forms occured to the writer's mind, when he began his inquiry.

The Pendulum Valve is a conical or wedge-shaped plug A, suspended like a pendulum from a support B in the side of the stove, with its small end in the air-entrance C, by which air is admitted to feed the fire. Evidently the current of entering air must impel the plug more or less inwards in proportion to the force of the draught, and the plug being conical, the more it enters the tube, the less space will be left around it for the passage of air. Thus increase of chimney-draught, by proportionally lessening the aperture, tends to keep the quantity of air entering and the amount of combustion always nearly the same. The rate of combustion may be permanently changed at will by a screw adjustment, causing the plug to hang nearer to or farther from the opening. As a very strong draught might cause the plug to close the opening altogether, and so to extinguish the fire, it is necessary to have a check to prevent the total closure in any case.

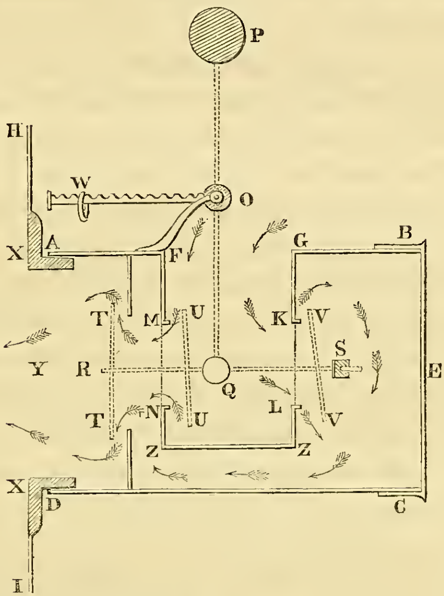
Fig. 7.

The Balanced Valve Regulator.

The Balanced Valve Regulator effects completely what is obtained only in a degree by the pendulum plug.—(Fig. 8.)

Description.—In the section here exhibited the regulator is supposed to be cut downwards through the middle to show the interior. The moveable

Fig. 8.



parts, all fixed together on the same frame, are sketched by dotted lines, and the solid external case and its internal divisions by entire or continuous lines. The external case is cylindrical or of canister form, A B C D, of thin metal, about four inches long and two and a half in diameter, for the middle size. One end of this is closed by a lid B E C, which fits on like the lid of a snuff-box or canister, and the other open end similarly fits on to the body of the stove, around the nozzle of the air-entrance to the ashpit. The fresh air enters the valve as indicated by the small arrows, at an opening F G, in the upper part, to reach the fire ultimately through two inner openings M N and K L, which have as doors two plates, U U and V V, suspended on the balanced wire frame P O R S, which moves on an axis at its centre of gravity O. The weight of the parts of this frame below the centre O is balanced by that of the ball of lead P above that.

Now as a weigh-beam, a wheel, or any other body, nicely balanced on its centre of gravity, is turned on that centre by the slightest force acting across any arm projecting from it, so the balanced moveable frame or pendulum P O R S, carrying on the arm R near the ashpit the flat plate T T, against which the whole current of air going to feed the fire blows, has its lower part moved or turned towards the stove by the slightest current or draught; and the exact force of the current can be measured by the weight W placed on another small arm O W formed like a steelyard, the end of which is seen to rise as the frame turns on its centre near O. Then further as the frame thus turns, two small plates on it, U U and V V, gradually obstruct or lessen the two openings M N, K L, through which the air enters, to impel the larger plate; which two plates, or air-doors, being placed so that the pressure of air on one is exactly balanced or neutralised by the pressure in the opposite direction on the other, the moveable frame is left to obey the force alone of the current acting on the larger plate T T. By this gradual closing of the outer doors, the force which urges the frame is correspondingly lessened as the frame moves; and consequently if any weight be placed on the steelyard or weight-lever W O, less than what the full current can lift, the frame will be turned, closing the outer doors until only as much current is admitted as will just balance the weight; and this balance will then be permanently maintained, however the chimney draught may vary. Thus the weight placed on the steelyard, and which may be varied at will, becomes the exact measure of the quantity of air admitted to the fire, and therefore also of the quantity of fuel consumed, and of the heat produced with uniform combustion.*

Such being the Governor by which the rate of combustion is completely regulated, there remains now to be described a construction of fire-place or stove, adapted to bring out all the derivable advantages.

The external form may be that of any graceful detached stove. The accompanying sketch, Fig. 9, shows a simple and common form. For some places the rounded shape is preferable; for others, the square or oblong shape.

The internal arrangement will be readily understood

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* References to Fig. 8.

X X. Parts of the nozzle surrounding the air-entrance.

Y. The air-entrance to the stove.

A B C D. The external case of the regulator.

F G Z Z. An internal cavity, open at the top F G, into which the air first enters.

M N and K L. Two smaller passages from that case towards the fire.

U U V V. The doors of those passages fixed on the moveable frame.

O. The centre of gravity, and of motion of the moveable frame.

P. A ball of lead at the top of the frame to balance the weight of the doors, &c. below.

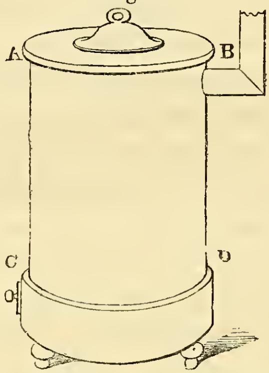
R S. The bottom wire of the frame carrying the two doors, and shutting them when it is moved towards the stove.

T T. A larger plate, also fixed on the wire R S, and against which all the air which enters at both the small doors blows, tending to move it towards the stove, and to close the two air-doors behind.

O W. A steelyard arm projecting from the centre of the frame, in the notches of which the weight W (an oval ring) hangs.

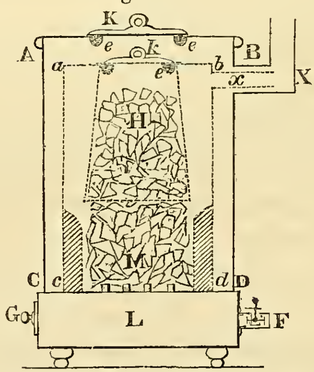
by any one who keeps present, as a standard of com parison, an idea of the common close stove described at page 118. The complete self-regulating stove may indeed be considered as a close stove, with an external

Fig. 9.



case, and certain additions and modifications now to be described. It is exhibited in the adjoining wood-cut (Fig. 10), where the dotted lines and small letters mark the internal stove, and the entire lines, the external case or covering.

Fig. 10.



The letters A B C D mark the external case, which prevents the intense heat of the inner stove *a b c d* from damaging the air of the room.

F is the regulating valve, for admitting the air to feed the fire. It may be placed near the ashpit-door, or wherever more convenient.

The letters *f f* mark the fire-brick lining of the fire-box or grate, which prevents such cooling of the ignited mass as might interfere with the steady combustion.

H is a hopper, or receptacle with open mouth below, suspended above the fire like a bell, to hold a sufficient charge of coal for twenty-four hours or more, which coal always falls down of itself, as that below it in the fire-box is consumed. The hopper may at any time be refilled with coal from above, through the lid *k* of the hopper and the other lid K of the outer case. These lids are rendered nearly air-tight by sand-joints, that is, by their outer edges or circumference being turned down, and made to dip into groves filled with sand, as at *e e*.

The burned air or smoke from the fire M rises up in the space between the hopper and the inner stove case, to pass away by the internal flue *x* into the other flue X of the outer case.

L is the ashpit under the fire-bars.

G is the ashpit-door, which must be carefully fitted to shut in an air-tight manner, by grinding its face or otherwise.

M is the coal intensely ignited below where the fresh air maintains combustion, but colder gradually as it is further up. Only the coal in the fire-grate below, where the fresh air has access to it through the fire-bars, can be in a state of active combustion.*

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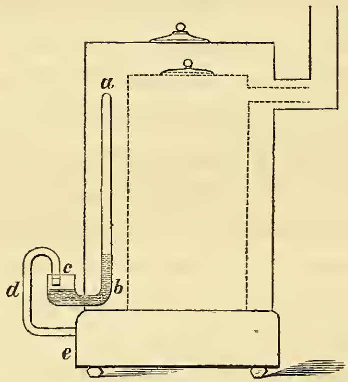
* A few observations regarding the making, fixing, and management of this stove are given at the end of the Appendix.

This cut exhibits an arrangement of much simplicity, by which the heat of the stove itself is made to

Fig. 11.



regulate the fire. It constitutes therefore, a true *Thermometer Stove.* The letters *a b c* mark a bent tube of glass or metal, having its long leg *a b,* which is closed at top, within the stove, and its short leg *c,* shaped like a cup, on the outside. A liquid (which may be oil or mercury), occupies the bottom of the cup *c,* the bend between *c,* and *b,* and a few inches of the long leg *a b,* as here shown. Another tube *d,* by which alone air can enter the stove to support combustion, has its mouth turned down into the cup *c,* towards the surface of the liquid there, on which surface a flat piece of wood floats. When the fire is lighted, the air shut up in *a b,* becomes heated and expanded, depresses the liquid surface in *a b,* to raise the surface and float in *c,* towards the mouth of the tube *d,* thus lessening or stopping the road by which air enters to feed the fire. This float is therefore, in fact, the valve-plate or stopper, which regulates the combustion. To enable persons to limit the heat of the stove to any desired degree, the mouth-piece of the tube *d*, is made to slide or screw up and down, through a certain distance.

In any of these forms there is a simple box of iron, of cheap and easy construction, answering all the purposes, in regard to mild and steady temperature, which expensive steam or hot-water apparatus could answer, burning its fuel as uniformly as an argand lamp burns its oil, or as an hour-glass lets its sand run through, and allowing the person who uses it, by merely shifting a weight W on the governing valve, rapidly to increase or diminish its heat, as by touching a regulating screw, or gas-cock, he could increase or diminish the light of a lamp.

What chiefly surprises a stranger in this new stove is the very small quantity of air required to support combustion which suffices to warm a large room: the whole might enter by an opening of about ¾ of an inch in diameter, and the quantity of air or smoke passing into the chimney is of course proportionally small. These facts at once suggest how small the consumption of fuel must be—for that depends on the quantity of air entering—how perfect the combustion of the fuel must be where so little is expended, and how completely the heat produced in the combustion must be turned to account. The combustion is thus perfect, because the fuel is surrounded by thick fire-brick, which confines the heat so as to maintain always intense ignition, although the combustion be slow; and the saving of heat is proved by the coldness of the flue, felt at some distance from the stove, indicating that little heat is passing up the chimney. For about sixteen years the writer of this has had his dining-room warmed by such a self-regulating stove. The fire in winter is never extinguished. The temperature is uniformly from 60° to 63°, and may be rendered as much lower or higher as is desired. The quantity of coal used (Welch stone coal) is, for several of the colder months, eleven pounds a day—less than two-pence worth—or at the rate of about a ton in six months—not very much exceeding the price of the wood needed to light an ordinary fire, and for this fire there is only one lighting in the season. The grate, or fire-box, with its hopper fully charged, holds a supply for forty-eight hours, and yet there is no waste, as the consumption is proportioned only to the air allowed to reach the fuel. Strangers entering another room in the house warmed by a similar stove, and noting the purity of the warmth, and that the stove was serving always as a table for a book-stand, have often thought that there was no fire there but that the agreeable temperature came from the kitchen below or some neighbouring room.

The self-regulating stove, as compared with other modes of warming, will be best understood, by reviewing its chief qualities.

I. *Economy of Fuel.*—This stove saves or puts to use very nearly the whole of the heat produced; because, first, it does not allow the air which has fed the combustion to escape, until deprived of much of its heat; and secondly, it does not allow any of the warm air of the room, except the little which feeds the fire, to escape by the chimney.

II. *Uniform temperature* in all parts of the room, and throughout the day and night. There is no scorching on one side, and chilling on the other, as occurs with a common fire. The occupants of a room are not obliged in winter to abandon their sofas or writing-tables, to crowd around the fire. There are no draughts in the room, nor layer of cold air on the floor. Again, with this stove invalids may have always around them, without watching or anxiety, the steady temperature which may be important to them.

III. *The Stove is always alight.*—This peculiarity, next to the saving of fuel, if not even before it, may be deemed a leading advantage of the stove, from which many minor advantages flow. Its importance is perceived by reflecting on the disadvantages of common interrupted fires, as—the trouble and expense, with smoke, dust, and noise, of lighting the fire every morning at least, and at other times when from carelessness or accident it has been allowed to go out —rooms becoming useless for the time when there is no fire, and valuable hours for labour being thus often lost,—the distress and often great injury to invalids from the fire ceasing during the night, or the scarcely less objectionable alternative of disturbed rest from attendants entering to trim or relight the fire. The early riser, student, or man of business, with his ever-burning stove and his clock set to awaken him at a particular hour, is very independent of seasons and of servants. It is because the stove is ever alight, that the temperature of the place warmed by it is so uniform, and that so much fuel is saved. More fuel is wasted in a common grate during one morning hour, by the attempt made suddenly to raise the temperature of a room which has become cold in the night, than by keeping the fire burning moderately all the night.

IV. *No smoke,* nor offensive gas can come from it, if properly arranged, for the only passage is the small opening by which air enters to feed the fire, and in this where the draught is weak a flap or valve is placed, allowing air to enter freely, but not to return. Neither will the presence of such a stove, because of the little air it requires, disturb the draught of other chimneys in a house, causing them to smoke, nor will it draw foul air from drains. As in these stoves fuel is used which produces no visible smoke, we may here remark, once for all, that when we speak of the smoke of the stove, we mean the carbonic acid or other invisible gases which rise from it, as they do from a charcoal fire, or gas flame, or wax candle.

V. *No dust* is produced, such as arises from poking common fires, and which is so hurtful to furniture, books, and articles of female dress. When the fire of the stove is stirred, or the ashes are taken away, any dust set in motion in the close ashpit naturally passes through the fire towards the chimney.

VI. *No danger to persons*, such as occurs when a child or an epileptic person falls against the bars of a common grate, or when a lady's dress catches fire by too near an approach. The fire of the stove is shut up in a double box, and is farther secured in the fire-pot, at a distance even from the sides of the external box; and never while the regulator is acting will the external surface become hotter than boiling water, or the particular degree fixed on. Then a cage of wirework may surround it, to prevent children or other persons from touching it. The chimney of the stove if proper fuel be used has no soot in it to catch fire; but if from any accident fire occur, then by shutting the valve it would be immediately extinguished.

VII. *No danger to property,* such as attaches to common fires. No live coal can be shot from this close fire to the carpet, and an accident is scarcely conceivable by which an object could be inflamed by it.

VIII. *Obedience to command.*—The weight on the regulator as certainly increases or diminishes the temperature, as the screw of a lamp affects the light; and by having a regulating thermometer accurately made and graduated, the very degree of heat required in any art—as in enamel-painting, tempering of steel, &c.—may be obtained with certainty. To manage tolerably an open coal fire is no easy art, as strangers to such a fire at first discover; but one lesson may teach a person to manage the stove, without failing.

IX. *The small expense of attendance upon it.*—A common fire requires an attendant to watch it at short intervals during the day; if used also through the night, one attendant will scarcely suffice.

X. *It may be used as a cooking-stove.*—A second small iron box placed within it, with a door opening outwards through the side of the stove, is a convenient oven—as is proved, indeed, by the common American stove, described at page 120, which in this respect resembles it. The top of the stove is a good hot-plate on which anything may stand, to be heated, or to be kept warm. If the stove be heated to a little beyond the boiling point of water, a tea-pot of cold water placed upon it, under a dish-cover, soon contains boiling water, and similarly eggs or other things may be boiled. Thus the breakfast of a solitary student in London chambers might easily be prepared by himself.

The list here given of the qualities of the self-regulating fire will appear not very closely to tally with the known performance of some stoves sold a few years ago, as being constructed according to the plans devised and published by the writer; but the paradox ceases when the true state of the case is known. As no patent was taken for the invention, all persons were at liberty to make or imitate and to vend stoves for their own emolument, in any way they might think proper. But the idea of a fire which should need none of the troublesome attendance required for a common fire was so new, that most of the manufacturers did not credit the possibility of accomplishing it, and many thought they were doing good by any approximation. Then as to making the self-regulator, of which various forms were described—this was a work of a more delicate kind than stove-smiths generally undertook: * most of the stoves sold at first were either altogether without such regulator, or had it so badly made that it was useless, or had a sliding-plate only at the air-entrance like the common Dutch stove, or the door and joints were so far from being air-tight, that there was no complete control of the quantity of air entering to the combustion. Such stoves could no more answer the intended purpose, than a watch can keep time without its balance-wheel; or than a ship can keep a steady course without a rudder. Then, some persons who had private interests likely to be affected by the adoption of the novelty employed themselves in speaking and writing against the stove, and were representing all the failures above referred to as faults of principle, not of execution. The writer happened to know that the most active of these

* The regulators are now supplied to the trade by Mr. Slater, of No. 23, Denmark Street, Soho, at 5*s*. each.

critics judged very favourably of what they were condemning. He could not engage in controversy with these persons without making a sacrifice of valuable time; and feeling confident that what was true would in due time be known, and satisfied with the approval of intelligent judges acquainted with all the circumstances, he waited patiently.

Many persons in England who think the stove well suited to warm halls, staircases, &c., still like it not for sitting-rooms, because the fire is concealed from view. It is impossible that there should not be most pleasing associations with the cheerful blaze and the fireside, around which, during the season of external cold and gloom, the happy family assembles; but on reflection it is seen that the English feeling in the matter is but an accident of our climate, for in other countries an opposite and as strong a feeling exists against the fire and in favour of the stove. In all very cold countries, like those of northern continental Europe, and America, in winter, the desired warmth of a room cannot be obtained at all with a common open fire; while the quantity of fuel consumed in the attempt is many times greater than that for the close stove, which warms completely. In these, therefore, the pleasing associations of comfort and safety are with the close stove, while any experience of open fires is likely to recall cold draughts, danger, and expense. But, even in this country, for certain apartments, a close stove of mild, self-regulated, uniform temperature, with a chimney-valve to secure good ventilation, and with a strong, beautiful, and cheap illumination of gas-lights under ventilating canopies, makes as comfortable and salubrious a room as the imagination can well picture

—such as the writer of this has had in his own dining-room now during many years. For persons accustomed to the open fire-place, however, it is satisfactory to know that the smokeless grate described in the first chapter of this book combines with the charm of the open fire, many of the health-guarding and money-saving qualities of the close stove.

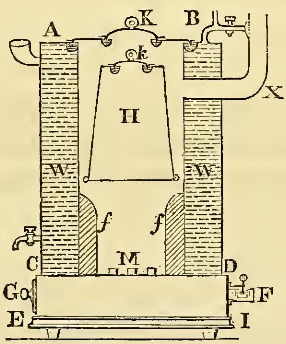
Some people again have the belief that a person is rendered very susceptible of injury from cold by living in rooms always heated to about 60°. But the temperature of 60° is a medium between the extremes of heat and cold, which persons may permanently use, and may at all times approach or leave with perfect safety. The danger of catching colds or heats is rather on entering or leaving draughty rooms with open fires, heated as rooms often are in this country to 70° or more, or cooled to 40° and below. During the prevalence of epidemic influenza and other winter diseases in England, it has been observed, that dwellings in which mild, uniform, temperature was maintained by action of steam, hot water, or otherwise, have given almost perfect security to their inhabitants.

SELF-REGULATION OF THE FIRES OF HOT-WATER AND STEAM APPARATUS.

It follows, that if the burning of a fire in a dry, close case, can be rendered quite uniform by the use of such a regulator as above described, the burning of a fire connected with a boiler can be similarly controlled; and that thus the advantages of the self-regulating fire may be combined with those of an apparatus for diffusing heat from circulating water or from steam, as spoken of in a preceding section: and further, that the precious convenience may be secured, of having always at hand, as part of the stove which warms any place, a reservoir of hot water for any purpose. The great importance of such an addition in nurseries, bed-rooms, sick-rooms, &c., can be conceived only by persons who have had experience in the matters.

It is evident that a boiler of considerable capacity may be placed over the fire of such a stove as represented at page 138, nearly where the coal-box H is shown, and that through a passage made in that boiler, the supply of coal may descend; but a much more convenient arrangement is that sketched in the

Fig. 12.



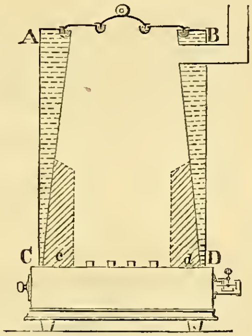
adjoining cut. The external case of the stove A B C D is double, and water, as represented by the short horizontal lines, is contained between the outer and inner plates or walls. This constitutes, what may be called, a water-clad stove.

The water is supplied at the funnel-cup A, and is drawn away for use at the cock near C. A small ball-cock may be connected with the cup or cistern A, to insure a constant supply of water. Any steam formed in the boiler may be allowed to enter the room from a small pipe and cock near B, or may be made to pass into the chimney-flue. With the exception of the double case, containing the water, the construction of this stove closely resembles that of the dry-stove, shown at page 138. The letters—

A B C D, Mark the external wall of the case.
W W, Water.
f f, The fire-brick, lining the fire-place.
H, The coal-box or hopper, holding the supply of fuel.
k, The lid of that resting in its sand-groove.
K, The external lid or coal door.
X, The chimney-flue piercing the water-case under the level of the water.
A, The funnel for water supply.
C, The cock, or tap at the bottom.
F, The regulator.
G, The ash-pit door.
M, The fire-bars.
E I, The bottom of the ash-pit, which is double, that air may be heated between the plates, to enter the chimney-flue by a suitable pipe, to warm the chimney and increase the chimney draught.

The double cylindrical case above sketched, when made of iron-plate with all the seams carefully riveted, costs much labour, and cannot, therefore, be very cheap. The writer was pleased, therefore, to find that the simpler and cheaper form, here represented (Fig. 13), answers for common purposes equally well. The outer wall is of iron-plate, formed into a cylinder, as in the other; but the inner wall is of conical shape, the lower part *c d* being of nearly the same diameter as the outer C D, and therefore allowing the two to be perfectly joined by one seam of rivets at C *c* D *d*. The top, at A B, is closed by a flat flanged ring or

Fig. 13.

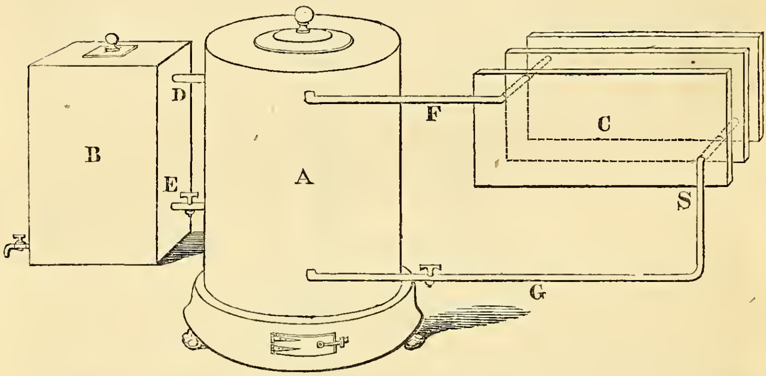


lid, not riveted but cemented in its place, which closure is sufficient where there is little pressure of water or steam against it.

One of the great advantages of the water-stove is, that the heating surface can be increased to any desired extent, by connecting with the boiler other tubes or vessels, to which the heated water may have access, and through which it may circulate. Thus the water-stove A, Fig. 14, being heated, a vessel of metal, plate-iron, or copper, B, may be placed beside it, having free communication with it through the tubes D and E. The water from the stove will then circulate through B, and will be always of nearly the same temperature as the water in A; and the surface of the vessel B will be so much added to the surface of A, acting to warm the air of the room.

If still more heating surface be wanted, it is very conveniently obtained by the arrangement C, pictured on the right-hand side of the stove. A number of very thin, flat boxes, made of sheet-copper and filled with water, are set up side by side, about half an inch

Fig. 14.



apart, in any convenient place, like so many thin portfolios or books of maps, and communication is then made between them and the boiler, by the two tubes F and G. The hot water from the stove runs along the tube F, which pierces and opens into all the boxes near their tops, and the water, when it has lost part of its heat, falls to the bottoms of the boxes, and is received into the other tube G S, which pierces or spits all the boxes near the bottom, and thus returns to the boiler to be warmed again. These thin boxes have been called water-leaves. The communication between them and the tubes which pierce them, is conveniently made, by having flat, solid rings of metal, about half an inch thick, surrounding the tubes between the boxes, and similar rings, with openings through them and the tubes, surrounding the tubes within the boxes; the whole being strongly bound together by screw-nuts, on the outside of the external boxes.* If the boxes are placed on a level with the stove, the cheaper form of stove, last described, suffices; but to warm water, for boxes placed higher up, as in the entrance-hall of a house where the stove is in the floor below, the outer case must be strong, as was described at page 149. The water-clad stoves may be of round or of square form, and of size to heat water for 100 or for 1000 square feet of heat-giving surface, whether of water-leaves or of water tubes.

The form of boiler, shown at page 149, is admirably adapted for a small steam-engine, rendering the action absolutely uniform, without needing the aid or interference of a watching engineer or stoker. This was shown in one instance, known to the writer, where such an engine worked a ventilating pump for months, night and day, having the attention only of a gardener, who put a supply of coal into the hopper every morning and evening.

The useful applications of the self-regulating water-stove are so numerous and important, that the author will probably publish a separate detailed account of them. He will merely add here, that he knows persons, who can scarcely find words which they deem strong enough to express their satisfaction with the performance of such a stove placed in a bed-room—a stove burning all the winter without interruption or change, and by night as well as by day—costing no more trouble to the servant than the winding up of a clock;—maintaining in the room always the same mild temperature, with perfect purity of air, allowing any quantity of hot water to be taken, for the pur-

* The same arrangement of water-leaves, with cold water, serves for cooling air in summer.

poses of foot-baths, washing, &.; or for making warm drinks, in case of sickness; the general effect being as if the parties were, at the time, living in one of the most favoured climates of the earth, although near them the snow may be lying on the ground, and the hardships and horrors of winter prevailing. One friend has had such a stove in use for more than ten years, and every year has been discovering new reasons for speaking in its praise.

Next to the bed-room use of the stove, above spoken of, the most important domestic application is to place one in the bottom of the house, with about 100 feet of water-leaf surface attached to it, to warm fresh air, allowed to enter under regulation; which air then ascends by the staircase to all the rooms of the house, destroying everything like damp in them, and preventing the colds so frequently caught, during winter, by children or other susceptible persons, as they pass through cold lobbies and staircases.

Uniform Climate for Invalids.

At the present day many invalids are sent from England, to winter in the south of Europe or in Madeira, away from beloved friends and home, and deprived of their accustomed comforts, because their own country has not offered them safe protection from the weather. Now, by uniting the agency of a self-regulating stove always alight, complete ventilation, proper diffusion of moisture in the air, double windows, and the use of the air-warming mouthpiece, to be afterwards described , the most desirable state of atmosphere, through both the day and the night, in the house and out of doors, is easily attainable.

PART FIFTH.

VENTILATION ON A LARGE SCALE BY PUMPS, FAN-WHEELS, SHAFTS, &c.

To reawaken the interest in regard to pure air and ventilation which the statements contained in former pages were calculated to produce, a few additional instances shall be presented here as a preface to the present section.

1. Early in this century, in the great Lying-in-Hospital of Dublin, it was ascertained that of 7650 infants born there within a certain time, 2944 had died before the end of their first fortnight, and chiefly from convulsive attacks. The house had been kept carefully warm, with a view to guard the health of the tender new-born; but owing to the little skill then existing in regard to the art of warming and ventilating conjointly, the warmth was obtained at the expense of ventilation. The managers at last suspected this, and the system was altered. After the change, the mortality quickly fell to about a third of what it had been before—proving the astounding fact that not long ago, in this kingdom, in a single institution, supported by benevolence,and manage d according to the average sanitary skill of the time, nearly 2000 lives had within a short interval been destroyed from ignorance of a truth which everybody should know.

2. When the French troops were last in Spain and were recalled, there were in hospital at Madrid about 160 sick and wounded, with pourriture d'hôpital, &c., many of whom were deemed unfit to bear the hardships of a march; but at their strong request, arrangements were made to take them away. When after two days' journey the wounds were uncovered to be dressed, it was found, to the general surprise, that most of them were healed, or rapidly healing. The fact was then manifest, that the men had escaped from the poisoned atmosphere of hospitals into the fresh air. Dr. Boudin, the eminent physician of the Military Hospital du Roule, near Paris, who reported to the writer this history of his own experience, related also other facts of kindred nature; such as that, in the French army generally, about three times as many men died of consumption as among men of the same age in the other classes of the community, which excess he attributed to the impure air of ill-ventilated barracks and guard-houses. The same high rate of mortality is found to hold in the English army, and doubtless from the same cause.

3. Respecting the hospitals at Scutari and Balaclava during the present war in the Black Sea, the correspondent of the "Times" newspaper, on the 6th of March, 1855, wrote thus :—"Neither medical skill, nor well-furnished kitchens, nor sedulous nurses, nor overflowing stores, will insure the recovery of the sick, if the atmosphere which they inhale is directly contaminated by the emanations from their own bodies, and if the first condition of health—that of wholesome air—is wanting in the wards. Already we have seen the terrible effects of this deficiency in the great hospitals at

Scutari, where wounds refuse to heal, patients contract even worse disorders than they bring, and the very surgeons and attendants fall victims to the manufactured plague."—"We saw during the outbreak of cholera in the Black Sea fleet last autumn, how the health of the crews was restored in a day or two by the simple expedient of a cruise from the infected shores. It was especially said of the Britannia's crew at the time of the cholera, that the attack assumed its terrible aspect only after the lower-deck ports had been closed in a gale."

4. In a London hospital, not long ago, a ward on the ground floor, called from the nature of the diseases treated there, the foul ward, in which there were usually sloughing sores and cases proceeding unfavourably, had to undergo repairs. The patients from it were removed for the time to an airy room near the roof. The great change for the better, soon apparent in the condition of the sores and in the health of the patients, surprised not a little those persons to whom the subject of ventilation was a new study.

The records of all past times bearing on the condition of persons brought together in crowds are full of such sad histories as those above given. The explanation is, that men, until within the last 200 years, did not know that air was a substance at all—did not know that it is a fluid having weight and accurately-measurable bulk and motions and momentum like any other fluid. They had not felt its weight, for the same reason that a man holding by a cord a bucket immersed in a pond, does not feel the weight of the water in the bucket until he attempts to raise it above the level of the surrounding water. They had not yet used air as stuffing for air-cushions, nor measured it out as accurately as other precious things—like the coal-gas now sold by the cubic foot for lighting, nor had they pumped tons of air every day through smelting furnaces to reduce ores. Persons now, however, are familiar with many such operations; but still popular misconceptions and prejudices hang about the subject, so as to impede singularly the adoption of good modes of artificial ventilation.

THE VENTILATING PUMP WITH CURTAIN-VALVES.

The writer has now to describe a ventilating-pump of great simplicity, which can be made, by any carpenter or dexterous man, of cheap materials to be found everywhere, by which, with very little labour, the air of a place may be changed as certainly as the water of a bath or cistern can be changed by the common water-pump or buckets. Pumps, or great bellows, had been proposed and used for ventilation by Dr. Hales, and others, a century ago; but they had defects which outbalanced their good qualities. The principal defect was the small size of the necessary clacks or valves, by which the labour of working the pumps was increased manifold, as will be explained below. Other mismanagement proceeded from not considering that, while in pumping water there is always the necessity to lift it more or less, which costs much labour, in pumping air, the air moved is always floating, or completely supported in the atmosphere around, as part of the general mass, and no more resists by its weight than the water which fills a wooden tub or bucket at the bottom of a well resists by its weight the raising of the bucket from the bottom to near the surface.

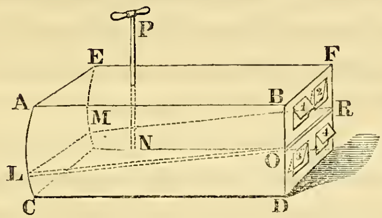
The whole subject will be illustrated by the supposed case now to be described.

If through a house, measuring fifty feet from back to front, there were a passage ten feet high and ten feet wide, quite open to the atmosphere at the two ends, a child who could easily push along on the smooth level floor of the passage a common wheel-chair or small carriage, could, in a calm day, push the same along with almost equal ease, although a sail were hoisted upon it, nearly filling the passage, as a piston fills a pump-cylinder, but without absolute touching or friction; and by so doing he would push all the air in the passage — which would be 5,000 cubic feet in the case supposed — out at one end of it, while an equal quantity would enter at the other. If such a passage were over the ceiling of the House of Commons, and were made to take its new air always from the body of the house, while it threw the old into the atmosphere, the child, by walking backwards and forwards a few times, would change the whole air in the House of Commons. In the case supposed, the effort required to move forward the sail or piston, and to displace and replace every cubic foot of air, would be little more than would move forward a large expanded umbrella ina calm; indeed just enough to overcome the inertia of the light air moved—so easy is it to move air which is among air. But if the supposed passage, instead of having its aperture or section at both ends of one hundred square feet, quite open to the air, were closed at one end by a wall in which there were an opening of only one foot square, evidently the 5,000 cubic feet of air in the passage, to be driven out in the same time, would have to move through an opening of one foot a hundred times faster than through the opening of one hundred feet, and would cause to the child or other power propelling it, merely from the different mode of moving it, an expenditure of one hundred times the force required in the first instance. If, farther, the air were both expelled from the passage by a small opening, and drawn into it by a similar opening, the waste of force would be again doubled. The air would be said, in any such case, to be "wire-drawn," both on entering and on leaving the passage; and the obstruction would be of the same kind as if, in one of the great water-pipes for the supply of a city, a strong plate or partition were somewhere placed across the pipe, with a small hole in it, through which all the water had to be squirted. The striking difference of power required in such a case is experimentally felt by a person who, with a common fire-bellows, first suddenly draws in or expels its fill of air through the clack or large valve behind held open by the finger, and then, shutting the clack, tries to draw in or expel the air in the same time through the small opening of the nozzle. He might crack the leathern cheeks of the bellows, and exhaust his own strength in the disappointing attempt.

Now, in the pumps for ventilation made by Dr. Hales and others in past time, the error above illustrated of wire-drawing the air, or forcing it to traverse with great rapidity small openings, has been committed to a most wasteful extent. The pump, or bellows, of Dr. Hales is here represented.

A B C D is a wooden box or case, ten feet long from A to B, five feet wide from A to E, and two feet deep from B to D. Within is a moveable partition or midriff, L M R O, which fits the box as a pump-piston fits the barrel, but loosely, so as to have little friction; and which moves like a door on a hinge at the end O R, with the other end, L M, sweeping up

Fig. 15.

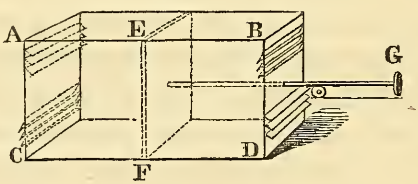


and down between A and C, when the partition flap is moved by the handle P of the piston-rod P N. As this midriff moves to and fro, with its edges distant only one-twentieth of an inch from the sides of the box, very little air in comparison with the whole escapes by the edges. The end of the box at A C E M is made curved to fit the motion of the piston. At the hinge-end of the box are placed the valve-openings 1 2 3 4, by which the air enters and passes out. The valves are flaps hanging on the outsides and insides of the openings. The valve 1 on the outside opens outwards, when the piston-handle is raised and lets the compressed air escape. At the same time the similar valve 3, below, which opens inwards, allows new air to enter beneath the piston. On reversing the motion of the piston, the valve 4 below opens outwards to allow air to issue; and the valve 2 above opens inwards to allow air to enter. The valve apertures were each only one forty-fourth part as large as the surface of the piston. He saw and complained of the obstruction caused by these small valves, but chose the dimensions because larger valves obstructed more the passage of air, by their great weight, and smaller ones by their narrower opening.

This air-pump or bellows of Dr. Hales, owing to the valves having only one forty-fourth of the area of the piston, caused expenditure of eighty-eight times the force which would have moved the air if there had been no such impediment. Great bellows with leathern sides, and moved by horses or water power, had been used by the Romans (Agricola de Re Metallica), to ventilate mines, but with the same fault, and Dr. Hales claimed only the improvement of facilitating the motion by dispensing with the leathern sides. The pumps of Dr. Hales were soon introduced extensively into ships, public buildings, mines, &c.; (see 'Transactions of the Royal Society for May, 1741,') but the use of them was ultimately abandoned, on account chiefly of the cost in labour to work them.

The writer of this, in studying the subject, saw that both impediments, that from the weight of the valve on one hand, and the smallness on the other, could be obviated, by forming the valve of a light curtain of

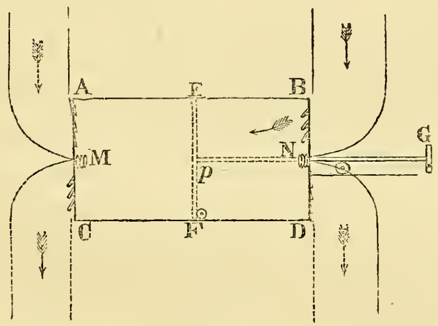
Fig. 16.



oiled silk, or other cloth resting against wire-gauze. Evidently, if a door or window, however large, had a frame of wire-gauze stretched across it with a curtain hanging on one side, air could pass from the other side without sensible obstruction, having only to push forward the light curtain; but air could not pass from the side where the curtain was, because the attempt would press the curtain against the gauze, and so completely shut the passage. In the supposed experiment made in the wide house-passage, described above, fit curtain valves at the extremities would convert the passage into a great pump.

The accompanying sketches represent the single ventilating pump.* Let A B C D mark a large case of

Fig. 17.



wood like a packing-case, made accurately square, resting on its side. Within the case is a moveable partition E F, fitting the box like the piston of a pump to within the 20th of an inch on all sides, so that it may be pushed to and fro with little friction and impediment. This moveable partition has a stalk or piston-rod P G, to the outer extremity of which G, a

* Fig. 16 being the body of the pump in perspective, and Fig. 17 being a perpendicular section, or skeleton, with dotted lines showing connected air-channels.

hand or other power may be applied to work it. The lower edge of the piston may rest and slide on two smooth bars or rails of metal, or may run on two small wheels at F to lessen friction, and the piston-rod may rest and run on another such wheel at O. Evidently, by pushing or pulling the piston towards either end of the pump-case, the air between the piston and that end will be driven out there, while an equal quantity will enter at the other end. To complete the pump, therefore, it is necessary only to have the case closed at both ends by valves, so that the air shall be free to move only in the directions desired. These valves are made by placing frames, supporting wire-gauze, across the ends A C and B D, and hanging curtains of light cloth against the gauze on the side to which the air is to pass, as represented here by the oblique lines. If the upper halves of the gauze-frames have curtains opening inwards, and the lower halves have curtains opening outwards, the direction of the air-currents when the piston is moved will correspond, and if the pump be four feet high and wide, and six feet long, containing therefore nearly 100 cubic feet of air, then a movement of the piston from near one end to near the other, will force about 100 cubic feet of air out at the lower curtain, while an equal quantity will enter by the upper curtain of the other side. By then reversing the motion of the piston, 100 cubic feet of air will be driven out at the bottom of the other side. Five double strokes of such a pump would give 1,000 cubic feet of air, and ten strokes might be made in a minute, giving 2,000 cubic feet, which continued would be a ventilation for 500 persons. A large ward in a hospital might have the whole air in it changed by such a pump in a few minutes. The valves of this pump may be a single curtain covering half of the end opening, or two or more narrower breadths, the lower edge of one of which overlaps the top of the next beneath, as here represented, like the slates of a roof or the scales of a fish. The piston at the end of its strokes is made to push against and compress springs M and N, from which it rebounds in a contrary direction with little loss of momentum, and the motion is thereby much quickened. The pump may rest on its side as here shown, or may stand on its end like a common water-pump or churn. The valves may be at the ends as here shown, or at the sides of prolonged ends. Air-channels connected with the valves which open inwards become exhausting or *vacuum* channels, and air-channels connected with the other valves which open outwards are forcing or *plenum* channels. The pump is therefore equally a forcing or an exhausting pump. It may be placed, as most convenient, within the place to be ventilated or without. It may be fixed in its position or may be a moveable piece of furniture, to be used, for instance, to draw air from the top of a window opened on a ball night. The dotted lines in Fig 17, indicate the channels to be connected with the pump, some of which may be of wood, some of canvas. By such a pump, therefore, air of perfect purity may be taken from any neighbouring situation, as from the top of a tower. to supply a dwelling placed where unwholesome effluvia might enter by the doors or windows.

The first use made of this pump on shipboard was in the 'Anson,' an old seventy-four gun ship, which in 1844 carried out 500 convicts to Van Diemen's Land, all of whom, with the exception of one who died of chronic epilepsy, arrived in remarkable health. Dr. Millar, the surgeon, on his return home addressed an interesting Report on the subject to the Admiralty, which was printed in the volume on 'Quarantine,' published by the General Board of Health. He had four such pumps made on board by the ship's carpenter, at the cost of about thirty shillings a piece. Such pumps have been used in various other instances, affording most satisfactory proof of their capabilities. But the author, hoping that the Scientific Committee, suggested at page 106, will be appointed to report on all such matters, does not here give farther details.

THE GASOMETER VENTILATING PUMP.

Another form of the pump with curtain valves is now to be spoken of, not quite so simple as that last described, but which has two qualities that under certain circumstances are very valuable—1st, from the avoidance of friction in the pump and of obstruction to the passage of air through it, so little force is required to work it that a part of the water usually supplied to a house from the waterworks of a town can be caused, while descending from a high cistern into which it first enters to the lower cisterns of a kitchen, wash-house, &c., to work the pump as regularly as a weight works a common clock or timepiece; and, 2nd, it delivers by measure any desired quantity of air, as accurately as the great gasometer or gas-holder of public gas-works delivers the gas distributed for burning. It is, in fact, a small gasometer, of the gas-work kind, converted into or made to work as the piston of an air-pump.

The first of the two following drawings recalls the construction of the common gasometer; the next shows a gasometer used as a pump, and driven by water descending from a high cistern to a lower; and the arrangement there shown is that which in 1850 was established in the new County Hospital at York, for the ventilation of that building. The following extract from the Minutes of the General Board of Health, dated October 4, 1850, relates to a trial of the apparatus, made while it was yet in the manufactory of the contractors, Messrs. Bailey, 272, Holborn, London:—

"The Board, accompanied by Mr. Austen, Dr. Sutherland, Mr. Rawlinson, and Mr. Rammell, having inspected the new engine and apparatus for the ventilation of the York Hospital, and having consulted their officers, were of opinion that the machine and arrangements were of a highly-important character, as going far to solve the question of cheap and efficient ventilation. In this case the cost of the ventilation of a building to accommodate 1000 persons would probably not exceed one shilling per day. Considering the importance, in a sanitary point of view, of an apparatus capable at so small a cost of regulating day and night, without superintendence, the quantity of air drawn in and out of dwelling and sleeping rooms, the Board deems it desirable to communicate with the Directors of the York Hospital, and to obtain from them the results of its practical working."

After two years' use of this apparatus, a committee, of which the chairman was the Rev. W. Vernon Harcourt, was appointed to report on the warming and ventilating of the new hospital. An elaborate

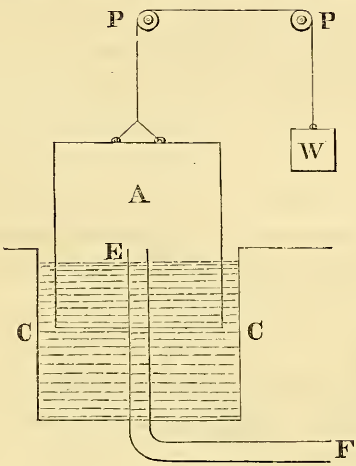
Report, and such as might have been expected from the high scientific standing of the chairman, contains as follows:—

"Upon the whole, the facts now put on record, as to the manner and extent in which the main requirements of a good hospital have been fulfilled, leave no reasonable doubt that the results of the method of warming and ventilation devised by Dr. Arnott, and of which, with a humanity wholly disinterested, he has given this Institution the benefit, are highly satisfactory, as far as our experience has hitherto carried us. In addition to all the ordinary means of effecting these objects possessed by other hospitals, we have a simple and durable apparatus which gives so complete a command over the three conditions of the *passage*, *warmth*, and *dryness* of the air, that the Governors have only to decide, under the advice of the Medical Board, the rate of the one, and the degrees of the other two, during half of the year, and to a certain extent during the other half also. This at least seems to be certain, that if there are any defects in the hospital, they are not to be referred to the general system of warming and ventilation."

The apparatus at York was the first of the kind set up. Had the hospital been in London, the deviser would willingly have superintended the execution of the work, and could have prevented some slight faults committed by workmen doing a thing for the first time; which faults, however, had no relation to the principle, and cannot occur again, as will be apparent to any judges or committee which Government may appoint to investigate the important subjects of ventilation and warming.

The common Gasometer, or Gas-holder.—Most persons are aware that the thing so named is a large

Fig. 18.

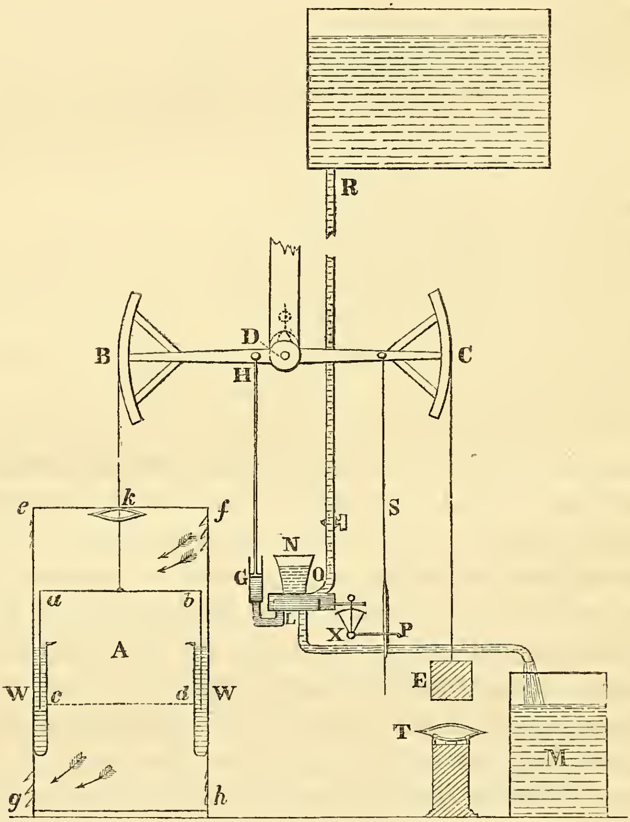


cylindrical vessel as A, of plate iron, hanging with its open mouth, B B, dipping into a circular trough of water below, C C, by which water the air or gas within it is confined or shut up. The vessel is suspended by one or more chains passing over fixed pulleys, P P, to a balancing weight or counterpoise, W. While the balance remains perfect, any air within is no more pressed upon than it would be if in the open atmosphere, but any weight laid upon the vessel, A, or taken from the counterpoise, W, causes compression of the air in the gasometer, and tends to force it out by any channel as E F. Such a vessel may, during the day, be gradually filled with gas, which during the night it may drive out to supply the lamps of a town.

The next figure represents in section the ventilating pump at the hospital at York, with the small water engine which works it.

A is the air cylinder, or gasometer, six feet in diameter, from *a* to *b*, and five feet deep from *a* to *c*

Fig. 19.



It hangs by a rope from the end of the beam B C, vibrating on an axis at D, at the other end of which beam hangs the counterpoise, E.

The cylinder moves up and down in a case, *e*, *f*, *g*, *h*, more than twice as deep as itself, within which, in its middle part, is formed as a lining to it a thin circular trough of water, W W, into which the open mouth of the cylinder plunges as it works. This case has at top and bottom curtain valves, such as described at page 162, and therein resembles closely the exterior case of the dry ventilating pump sketched at page 163. When the cylinder descends it drives out its own bulk of the air beneath it through the valves, indicated by oblique lines at *g*, which air enters the ventilating channels of the house, and at the same time an equal quantity of fresh air is admitted to the pump at the valves *f*, to fill the space behind the descending cylinder. When, with the reverse stroke, the cylinder is made to ascend again, it drives its own bulk of the air above it into the ventilating air-channels through the valves at *e*, while a corresponding quantity is entering at the valves *h*. Thus the metallic cylinder becomes in effect a piston, with an air-tight packing of water, working within the external wooden case which constitutes the barrel of the pump. Whether the cylinder be rising or falling, air is equally being pumped onwards.

The cylinder of this pump, which contains about 125 cubic feet of air, in completing the stroke up and down, moves forward 250 feet; and as the intention was to give to the hospital a ventilation of 2000 feet per minute, eight complete strokes of the pump per minute had to be made, and are made as now to be described.

A small water engine, formed like a syringe or forcing pump, one foot long or deep, and two inches in diameter, is placed below the beam at G, with its piston-rod, G H, connected with the great beam at H. When water is then allowed to descend by a pipe, R O, from the tank R, placed sixty feet above the pump, to enter beneath the piston of the small barrel, G, and to press on the under surface of the piston, which has an area of nearly three square inches, with the force due to the elevation of sixty feet, of nearly thirty pounds on the inch, the piston, by its rod G H, presses upwards the pump side of the great beam with a force of about ninety pounds, and thereby lifts the great ventilating cylinder, A, to its highest position. At that moment a cock, or valve at L, acted on by a rod, S, from the beam, is made to shut off the stream of water from above, and at the same time to open a way for the escape of the water in the syringe to any low reservoir, M; and the cylinder A, which is heavier by a certain amount than the counterpoise E, being thus free, makes its downward motion by its own weight, and so completes the double stroke. The water-cock is then opened again by a touch from the rod, S, which works the valve, and so the various actions above described are repeated and continued as long as there is water in the high cistern, R.

The small water-barrel, G, holds nearly a pint of water, so that every pint of water, descending from the high reservoir, sends 250 cubic feet of air into the hospital; and eight pints, therefore, or a gallon per minute, gives the required ventilation of 2,000 feet in that time. There being 1,440 minutes in twenty-four hours, that number of gallons costing, in many places, at the rate of sixpence for 1,000 gallons, would, even if used for no other purpose, cost only a trifling sum. And that, with a fresh leather packing for the syringe, once or twice in the year, becomes the whole working-expense of the apparatus.

The letter N marks a compressed air-vessel connected with the valve. The letter T marks a spring, placed on the floor, to receive the downward momentum of the counterpoise, and to cause that to rebound quickly without loss of force. There is a corresponding spring connected with the cylinder. The sketch of the arrangement, originally proposed by the writer for ventilating and warming the York Hospital, is printed at page 224 in the Appendix. The whole of the air pumped into the Hospital during the cold season, is warmed to the exact degree desired by the self-regulating stove with water-leaves, described at page 152; and if in very hot weather it were desired to cool the air, the end is obtained by establishing a communication between the leaves and a cistern of cold water.

Besides pumps and bellows of various kinds, there are used also for ventilation, on the large scale, *fan-wheels, heated capacious shafts, steam-jets, &c.*

The writer does not mean here to describe these in detail, as a full examination and comparison will probably be made ere long by public authority. He will merely remark here that—

Fan-wheels have to be driven with great rapidity, wasting force, as described in the remarks on wire-drawing of the air of ventilation at page 160, and marking very indistinctly the amount of air injected or extracted. If the channel, through which a fan-wheel is forcing air, be partially obstructed by any accident, or altogether closed, the wheel then moves more easily, because the quantity of air entangled among its leaves remains there and becomes as part of a fly-wheel, the worker not being warned of the impediment.

Great Heated Shafts, admirable in mines, have, in buildings, very irregular and feeble action compared with the pump, and are much more costly. When placed in hospitals or other places, where there are open fire-places in the rooms, there is the grave error of setting to work together, two forces which are in their nature antagonistic. If the shaft-action be strong, it tends to make the chimneys smoke. If it be weak, the chimney-draught overpowers it, and causes it to become, in winter, a dangerous inlet of cold air instead of an extractor of the foul air. If enough fresh air be admitted to the house to let both shaft and chimneys act, the quantity will be so great as either to cool the building much, or to occasion much greater expenditure of fuel to warm sufficiently. Then, even in the summer, a fire must be kept burning in connection with the shaft to make it active. The failures and disappointments from shafts have been very numerous in hospitals, lunatic asylums, prisons, &c.

The Steam-jet is another not very obedient or satisfactory device, requiring high-pressure boilers, which may be dangerous, unless under the management of skilled attendance costing considerable wages.

All the three thus (although in particular situations they may be used with advantage) rank in point of expense and efficacy below the ventilating pump, driven by water as above described, which is perfectly automaton or self-regulating.

PART SIXTH.

VENTILATION AND WARMING CONJOINED—HEAT-TRANSFERRING APPARATUS.

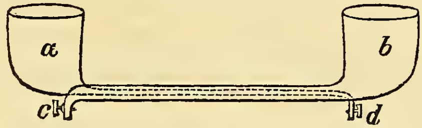
There is a fact in regard to ventilation, as affecting warmth, very important but little understood by persons in general, which has here to be explained. A lady sitting in a crowded assembly, where the thermometer stands at 70° or 80°, feels oppressed by the heat, and yet experiences relief from blowing the hot air against her face by a fan. To many it may at first appear odd that hot air should thus refresh and cool—which it really does; but the explanation is easy. The temperature of a healthy human body is 98°, in a crowd perhaps 100°; now the air in immediate contact with the skin sticks in a degree to it, and acquires its temperature, forming, therefore, what may be called a covering to it of warm-air flannel. The adherence continues more or less as long as the surrounding air is calm; but if new air be driven against the skin by a fan or bellows, or a current of wind, called a draught, entering by a door, window, or other opening, the new air brushes away the old, and, taking its place, is an application colder than the old, by the difference between its temperature and 98° or 100°. The action of fanning, therefore, in a warm room tends to cool the skin 20° or 30°. Such a difference is borne with impunity by a person in health, but a partial stream from the external atmosphere, perhaps 50° colder than the body, is often destructive, as recalled in the proverb—

> "If cold winds reach you through a hole,
> Go make your will, and mind your soul."

These considerations explain why sharp currents of warmed air, entering the Houses of Parliament during the experiments recently made there, were thought to be blasts of very cold air admitted from defects in the apparatus. In the old Fever Hospital of London, Dr. Armstrong, the physician, told the writer of this that not a few patients, after the subsidence of the fever, had died of inflammation of the lungs, produced by cold draughts allowed to enter near their beds, through direct openings in the walls. In some cases, where ventilation has been sought by fan-wheels injecting the air with great rapidity through narrow channels, and delivering it into the wards as sensible sharp currents, evil of the same kind has arisen. Any sharp draught among the enfeebled inmates of an hospital are dangerous. The safe ventilation is that which enters copiously, but almost imperceptibly, like the gently-moving air under a tree or an open arch in a nearly-calm summer day.

Double-current warming ventilation.—The writer has now to describe a new mode of ventilating, by which the hot impure air, as it passes away, is compelled to give up the whole of its warmth to the pure air entering to take its place. He had ascertained the possibility of doing this many years ago; and in his "*Elements of Physics*" explained it thus:—If a quantity of boiling water be placed in a vessel, *a*, and be allowed to run along a very thin metallic tube, from *a* to *d*, where it escapes with speed regulated by

Fig. 20.



the cock at *d*; and if, at the same time, an equal quantity of water, at freezing temperature, be placed in the vessel *b*, and be allowed to run along a larger tube, *b*, *c*, which also includes, or envelops, the other, to escape by the cock *c*; the hot water from *a*, losing, every instant, some of its heat to the counter-current of colder water surrounding it, must, at a certain distance, if the tubes be long enough, have lost the whole; while, on the other hand, the same quantity of the originally cold water from *b*, acquiring every instant, in its passage along the tube, *b c*, the heat passing from the tube of hot water within it, will, when at last discharged, have gained all that the other lost.

In an experiment made with an apparatus of thin flat tubes, only six feet in length, boiling water was cooled to 34°, and freezing water was heated to 210°.* Thus, by making the two currents run counter to each other, in almost mixed contact, there is not, as in former processes, merely a mixture of two temperatures producing a double quantity of a middle

* The writer has lately learned from Professor Faraday that Sir Humphry Davy, at the request of some inquirer, made an experiment which confirmed the view here taken, but which did not lead to any practical result in art.

temperature, but the whole excess of heat of the one is given, with very trifling loss, to the other; and the hot water, which might be the foul water of a bath just used, has become the cold water; and the cold water, which might be pure water for a bath intended, has become the hot. Now the same transference of heat takes place, where the counter-currents are of any other fluid, of air, for instance, instead of water; and, therefore, the very heated impure air, which accumulates at the top of an enclosed space containing a crowded assembly, may, as it passes away under the influence of a ventilating pump, be made to give up its whole warmth, or as much of it as desired, to an equal quantity of pure air, entering from another pump. And where there may be a considerable number of persons present, no other heating apparatus will be required but the lungs of the company. This mode of warm ventilation is applicable generally from the case of an assembly of thousands of persons in a church or theatre, through the descending series of courts-of-law, ball-rooms, schools, sitting-rooms, even to that of a single person, who, wherever placed, may send out his warm breath through one tube, to warm the pure air drawn in through another tube, surrounding the first.

For this kind of double-current ventilation on the large scale, the air-measuring pump described in preceding pages is an essential part of the apparatus; for evidently the increase of temperature acquired by a given quantity of entering air must depend on the quantity of hot air from within, which passes during its entrance. In general it is desirable that the two quantities should be equal, and the ventilating pump described being of double action, equal in both directions, one end may be used to inject the fresh air, and the other to extract the foul.

Breath-warmers.—The process above described, for transferring heat from impure air about to be dismissed into the atmosphere, to pure air about to be applied to use, will, by many readers, be deemed quite new; and yet, in a less perfect form, it has been a popular practice in Europe from time immemorial. When a person going out of his house into the cold air of winter, ties a bulky woollen handkerchief, called a "comforter" or "fear-nothing," around his neck and face, or holds any such porous mass over the mouth, that he may breathe through it, he is really applying, although imperfectly, the same principle. His warm breath, going out through the handkerchief or other mass, or between the internal surface of the mass and the cheek, leaves warmth there, and then the cold pure air, drawn towards the mouth through the heated mass, absorbs a great part of the detained heat, and enters the chest of the individual much less cold than the air of the atmosphere around. The hackney-coachmen of Paris and other continental cities are rarely seen in winter without such a defence; and in all countries, medical men commonly desire patients, with tender chests, not to pass, even from one room to another, through a cold staircase, without such protection.

In 1836 a useful modification of this simple process was pressed on public notice by Mr. Jeffrey, a medical practitioner recently returned from India. He had been present at a lecture on warming and ventilating delivered by the writer of this, at the Royal Institution in the winter of that year, and a few days after he called to submit to the writer what he deemed a new proposal for which he desired to obtain the advantages of a patent. The writer was not then aware that the same proposal had been made and executed, and published forty years before—as seen in the quotation given below,*—by Dr. Thomas Beddoes of Bristol, in whose laboratory Sir Humphry Davy got some of his early lessons in chemistry and philosophy; and he could not therefore point to that fact as an objection to the patent, but he expressed regret that an educated medical man should risk the being confounded with advertising quacks. He finally, however, expressed his intention to speak approvingly of the proposal in the forthcoming pamphlet of his lecture on warming and ventilating. The following is what he then wrote on the subject:—

* Hygeia, or Essays Moral and Medical on the causes affecting the personal state of our middle and affluent classes. By Thomas Beddoes, M.D., 1802. Vol ii. pp. 86 and 91.

"There is, however, one most simple expedient which I have been lately accustomed to recommend, and which certainly has allowed some invalids to range more at large with impunity. It is merely an improvement on the common practice of holding a handkerchief to the face, on coming out of a hot room, and consists in a sufficient number of folds of gauze over the mouth and nose. The invention is not merely to warm the air before it enters the respiratory passages, but likewise, when the weather is dry as well as cold, to give it moisture." "It is obvious that the construction of these *muzzles* ought to vary according to the case. Each individual will soon find how many folds of whatever material he may choose to employ will communicate heat and moisture enough to the air he breathes without injury to the freedom of respiration." "It is obvious that the consumptive and asthmatic will be enabled by the same means to indulge safely in air and exercise at times when otherwise they must debar themselves the use of both."

This description, put as a working-direction into the hands of any adroit mechanician, would produce a good form of what has been sold as the patent respirator.

"He (the patentee) substitutes, for the bulky handkerchief, or texture of common thread, a less bulky texture, yet more quickly heat-absorbing, of metallic thread or wire—in fact, folds of fine wire-gauze, or pierced plates of metal, which, when fixed in a light frame, form a compact mouthpiece fitting closely around the lips, and leaving free passage for the air between the numerous apertures. The folds or plates are heated by the warm breath passing out, and then give up the heat so acquired to the pure air passing in. The contrivance may be called the "comforter" or "fear-nothing" of metal, and it has the advantages of being less bulky, of retaining less of the impure air in it, and of allowing speech to be heard through it, almost as if there were no interruption. The effect of a good means of this class is to give in reality an artificially-warmed atmosphere to a person walking out in the open air, as if he were still in his room heated by a fire. It may be regarded as a portable warm room, or a suit of warm clothing for the lungs. It affords a valuable security to persons labouring under certain kinds of weakness or disease of the chest, and who are compelled by their duties to leave home; and it will allow many persons who, without it, would be confined to their rooms all the winter, to walk abroad with impunity. It is an addition made by art, to the beautiful provision already existing in nature, of the long narrow channels of the nostrils and throat, which have considerable effect, by their warmth, in tempering the air which passes through them to the lungs. The arrangement of metallic threads or plates, forming the air-warming mouthpiece, has been called, by the proposer, a *respirator*, (a name, it may be remarked, scarcely more suited to a breath-warmer than that of a *drinker* would be to a cup,) and has been made the subject of a patent. We may regret that, in this country, there should be no other provision for rewarding men who make useful suggestions, but by allowing them, even where the public health is concerned, to levy a patent-tax, which may fall heavily on persons who can little afford to pay it, as in the present instance, where a great many of the persons needing the new means of relief are among the poor, already, perhaps, suffering from want of clothing and fuel; and the price charged for the first of the wire-gauze instruments was so high (from two to three guineas), that only the rich could afford to buy them; and it was not pointed out that a pennyworth of wire-gauze folded in a handkerchief would be a useful breath-warmer for a poor person: they are now cheaper. —We may remark, with respect to the wire-gauze, that the temperature of the air inspired through it is unequal, being much higher at the commencement of the inspiration than towards the end, when the metal has already given up nearly all its heat. A single plate of wire-gauze held in contact with the lips is felt in a cold day to become very warm while the breath is passing out, but to become cold as a piece of ice while the fresh air is passing in. A perfect uniformity of temperature is obtainable, by using a suitable modification of the double-current apparatus, of which I have spoken above. For this purpose is required a mouthpiece, from which one or more channels, of thin metal, may carry the hot breath to the atmosphere, and to which other larger channels, surrounding the first, may bring pure air from the atmosphere, the currents being kept quite distinct by simple valves in the channels. The apparatus may be made to resemble a cane held to the mouth, or a Turk's pipe, or it may bend round the neck, and be concealed in a cravat. Because twice as much heat issues with the breath as is wanted again, a person will not lose the advantage of the apparatus, by detaching his mouth from it occasionally, to take part in an ordinary conversation."

Considering that the myriad little cells of the lungs into which the air of the breath enters, have greater extent of surface than the whole external skin, one sees that great abstraction or waste of animal heat must be caused by the breathing of very cold air. And as it is now ascertained that the animal warmth is maintained by a kind of slow combustion in the lungs, of a part of the food which is taken serving as fuel, it is explained why so much more and stronger food is required in cold countries and seasons than in warm. A farmer, who, during part of a winter had to feed his sheep on turnips, tried the experiment of giving shelter to a certain number, while he left the rest exposed to the sky; he found that those which were sheltered, not only consumed fewer turnips, but became fatter than the others. It appears, then, that breath-warmers for human beings, while in many cases giving much comfort and safety, might also in some effect economy in food, fuel, and clothing. Advantage might be expected for sentinels exposed during the severe frosts of winter nights; for sailors, necessarily remaining on deck during the night-watches in cold weather; for hackney-coachmen, sitting in the open air; for the indigent with very scanty clothing, &c. In all the published prints representing soldiers in the field, exposed at night during a winter campaign, as in that of the Crimea in 1854-5, the men are shown with bulky neck-wrappers rising high over the lower part of the face. Most persons suppose that these wrappers serve merely to protect the throat from the cold; but the fact is, that they are also potent breath-warmers, adopted from a kind of instinctive feeling, which, besides allowing some air to press through their substance, form a partially-enclosed space between their internal surface and the cheeks, the sides of which are warmed by the hot breath passing out, nearly as a man's gloves and fingers are warmed in winter when he blows through them, and the fresh air passing towards the mouth coming in contact with the same surfaces, is considerably warmed before it reaches its destination.

Lately, Dr. Stenhouse, Lecturer on Chemistry at St. Bartholomew's Hospital, has proposed to construct a breath-warmer of the usual appearance, but which is a light case or cage of thin metal filled with a layer of charcoal broken into small fragments. The intention is not only to warm moderately the entering air, but where there is any foul effluvium in the air which a person is obliged for a time to breathe, to purify that air by filtration. The remarkable power of charcoal to absorb impurity from decomposing animal and vegetable substances is well known.

A mode, recommended by the writer in his "*Elements of Physics,*" many years ago, of keeping and using the warmth of the breath, was an extension of the common practice of blowing into one's hand covered with gloves, to warm them; namely, for persons going to bed with cold feet, which might probably keep them awake for hours, and spoil their night's rest, to send their warm breath down to the feet through a tube.

We may here observe, how applicable the double-current apparatus is to the purpose of drying substances. In the air of a room full of damp, recently-printed paper for instance, or of wet linen, evaporation or drying takes place only until the air be saturated with moisture, and then stops; but if the moist hot air be constantly passing away, and be caused to give its heat to dry air entering, the new air will at once take a second load of moisture, and on going away, will leave its heat to aid in removing a third load, and so on.

GIVING MOISTURE TO AIR.

Our atmosphere contains—besides the two constant elements, of one measure of oxygen, and four measures of nitrogen—also a variable quantity of moisture or aëriform water. This is constantly rising into it, under the influence of the sun's warmth, from the exposed surfaces of water on the globe, and descending again, to be useful to animals and vegetables, in the forms of rain, mist, dew, &c. Even while invisible in the atmosphere, too, it is supplying essential wants of animals and vegetables, as is discovered when the air—as in the African simoom, and other dry winds—is nearly devoid of it, and then withers up and blights vegetable nature, and much distresses animals. The quantity of water which can be sustained invisibly in the air, has a fixed proportion to the temperature of the air; and where the air has much less than this proportion—as when clear frosty air is artificially heated, without addition of moisture—it is felt to be dry or thirsty, that is to say, powerfully absorbent of moisture. To make the atmosphere of a winter room, therefore, congenial to man's nature, it is generally necessary to give it a proportion of moisture as well as of heat. This is rarely done in England, where there is an open fire, unless, perhaps, where a physician may order it, to lessen the violence of hooping-cough or other chest irritations; and, in the close rooms of carefully-constructed houses, this becomes very important. Where high temperature with dryness of the air is pretty constantly maintained, whether by open fires, close stoves, or pipes of hot water, remarkable effects are produced on the wooden furniture. The various objects are observed soon to bend or warp, to crack or splinter, to be loosened at the joints, &c.; pianofortes are ever out of tune, and so forth. The prevention or remedy of these evils is very easy—namely, by a small boiler placed on or near the fire, from which a tube, rising above the chimney-piece, may jet the required quantity of steam into the room. This addition to a fire-place may be formed and placed so as not to attract the notice of visitors.

Invalids, requiring to pay particular attention to this point, may be directed by a hygrometer, which will always indicate the degree of moisture existing in the air. The difference well known in England between a north-east wind, which, to most persons, is disagreeable, and to many very hurtful—and a south-west wind, of the same temperature, which, on the contrary, is, to the sense of almost everybody, bland and refreshing—is chiefly in the proportions of moisture. Means, then, which enable us to control the moisture as well as the temperature of the air, may almost be named means of calling up at will, or of manufacturing, a south-west wind.

The subjects of warming and ventilating, although in themselves simple, still deal with things and motions which are impalpable and invisible, and must be studied in their principles to be understood at all. Where the bodily eye can see nothing, the mind's eye must note important processes. The peculiarity of the subject is proved by the fact of so many distinguished architects and engineers failing signally in undertakings to warm and ventilate.

GAS-LIGHTING.

In treating of the ventilation of dwellings, it would be a great fault to omit speaking of gas-lights, which in great towns have now become almost universal. Because there is no visible smoke, and little odour, from gas which is completely burned, the uninformed populace believe that little or nothing is to be apprehended from the burned air being allowed to diffuse itself and to remain in the room; but this is a dangerous misapprehension. The products of the combustion of gas are water and carbonic acid, which last-named is the same as the deadly invisible smoke of charcoal, and is what, when collected in mines, is called *choke-damp.* The deaths occasioned by gas explosions in coal-mines are owing much more to the choke-damp which is left after the explosion, than from the heat or mechanical violence which precedes it. A chimney for gas-lamps is therefore almost as essential to the maintenance of pure atmosphere in rooms, as the chimney for the fire. This consideration points directly to one of the important uses in modern houses, of the ventilating chimney-valve, described at page 36, which valve, even alone, removes much of the objection to gas, or to lights of any other kind (for oil and wax in burning produce choke-damp in proportion to the light given out by them); but with tubes leading directly from inverted cups or funnels placed over the flames, the valves obviate every objection, and make a much purer air in a well-lighted room than our forefathers ever could enjoy. In the Appendix is reprinted a letter on the employment of gas, which the writer published on the occasion of a gas accident in the year 1848.

CONCLUSION.

Having now passed in review the general principles of warming and ventilating, and the chief means as yet known of effecting the purposes, and having entered into details which are meant to serve as working directions in regard to the most important application of these means, namely, that for securing comfort and safety to the body of the people in their ordinary dwellings, it only remains for the writer to observe that very different forms and combinations of the means are required for special cases which present themselves in the progress of civilized communities—as will be perceived by any one who considers the following list:—

1. Private Dwellings.
2. Churches.
3. Schools, lecture-rooms, dormitories.
4. Houses of Parliament.

5. Courts of Justice.
6. Theatres.
7. Assembly-rooms for oratory, music, balls, &c.
8. Exhibition Palaces.
9. Hospitals and Lunatic Asylums.
10. Prisons.
11. Barracks and guard-houses.
12. Union poor-houses.
13. Workshops and manufactories.
14. Ships for merchandize, passengers, troops, cattle, &c.
15. Stables or houses for horses and cows.
16. Houses for wild animals from different climates.
17. Hothouses and artificial climates for plants.
18. Mines—prevention of explosions.
19. Sewers.
20. Public and private carriages, &c.

The writer has collected a mass of information respecting these cases of which the statement would occupy another volume as large as the present; but hoping that subjects so important will soon engage the attention of a Scientific Committee appointed by Government, as suggested at page 106, he defers for the present entering into farther details. As an example, however, of the adaptations required in particular cases, he may refer to the apparatus for warming and ventilating the new County Hospital at York, already described at page 170. The original sketch of the plan printed in the Appendix, at page 224, was prepared by him for the governors of the hospital at the request of their able chairman, the Rev. W. Vernon Harcourt, with whom he was much pleased to be associated in this work of charity. Another example is offered in the account, also printed in the Appendix, of a dormitory which the Earl of Shaftesbury, in the exercise of his benevolence, caused to be fitted up under the room of the Ragged School in Field Lane. And another in the account at page 228, of what has been done in a ward of the Royal Hospital at Chelsea.

In consenting to give his assistance in such cases to public bodies and Government authorities, the writer, fully engaged at the time in the practice of his profession, trusted that the General Board of Health then existing, to which on request, at various times, he had rendered services, would have deemed it part of their office or duty to watch and aid in the prosecution of works undertaken for the good of the public health by a person having no private interest in them, and particularly after trials so promising had been made as that described in the minute of the Board (see page 167), on the York ventilating apparatus; but it did not happen so: and, as was to be expected, although every trial gave proof to intelligent judges of the soundness of the principles and views involved, still in some cases the obstacles likely to arise from ignorance, prejudice, and adverse private interest, as spoken of at page 105, and which could be quickly counteracted only by some intelligent public authority, were curiously exemplified. But the Board was itself a novelty, and had soon after to be remodelled. The writer now hopes, however, that the present work, by making intelligible to popular apprehension the scientific principles concerned in the successful execution of all such undertakings, will remove many difficulties, and benefit society.

APPENDIX.

COMMISSION OF INQUIRY RESPECTING THE EPIDEMIC AT CROYDON IN 1852–3.

(Referred to at p. 90.)

Letter appointing the Commission.

GENTLEMEN, *Home Office, February* 14, 1853.

A REPRESENTATION having been addressed by the Chairman of the General Board of Health to Viscount Palmerston, to the effect that fever had sprung up and spread itself extensively in Croydon since the establishment of new works for draining and supplying water to that locality, that it has been suggested that these works have been influential in producing the disease, and that an inquiry should be instituted for the purpose of ascertaining whether that suggestion is founded on reasonable grounds, I am desired by Viscount Palmerston to direct you to proceed to Croydon for the purpose of undertaking the proposed Inquiry; to ascertain from the Reports of the Local Board of Health, from the testimony of intelligent persons whose attention has been drawn to the subject, and from any statistical evidence which may exist, whether the character of the fever differs from that which has appeared in other places during the late unusually wet season. You will seek the cause of the difference, if there be any, and at any rate that of the wide prevalence of the disease at Croydon.

The inquiry should include the examination of the works recently constructed, and your attention should be directed to the mode in which they have been planned and executed.

Viscount Palmerston can have no doubt that the General

Board of Health, and the Local Board at Croydon, will give you the necessary facilities for the prosecution of this Inquiry, the result of which you will report for his Lordship's information.

I am, Gentlemen,

Your most obedient Servant,

(Signed) H. FitzRoy.

Neil Arnott, Esq., M.D.
Thomas Page, Esq., C.E.

MEDICAL REPORT.

BY DR. ARNOTT.

General View.

The main facts which have led to the present Inquiry, are, that in Croydon, where no such epidemic is known to have occurred before, there have been since August last, in a population of about 16,000 persons, about 1,800 cases of fever, with a mortality of about 60, and very numerous cases of diarrhœa and dysentery, with mortality of about 10; and that all this has happened during and since the execution there of new works, intended to improve the sanitary condition of the place.

The inquiry resolves itself into two questions—the first, as to the relation of the Croydon epidemic to the fever which has appeared in other parts of the country during the late unusually wet season; and the second, as to the causes of the wide prevalence of the illness at Croydon.

To the first question the answer obtained is, that the disease has been of the nature of the fever which in this climate appears mostly in foul and wet localities, where there are malarious effluvia from decomposing organic substances, and which has prevailed this season in various parts of the kingdom; and that it has had more than usual of the gastric or bowel irritations which commonly arise where the influencing malaria contains more than usual of impurity having animal origin.

To the second question, the answer cannot be so simple; for many evident causes and modifiers of noxious malaria have been acting in Croydon during the last season, the greater part of them accidental and transient, but some of more enduring nature. They are set forth in the following paragraphs:—

1. The site of Croydon has a remarkable geological peculiarity, which may be turned to good or evil, according as it is dealt with. Large quantities of water spring from the earth in different parts of the town and neighbourhood, meeting all in the lowest part, near the church, to form at once the considerable stream the Wandle. One of these sources, called the Bourne, by its great magnitude and apparently capricious outpourings, long excited popular wonder. It bursts forth a short way above the town, at irregular intervals of from one to ten, or more years, and after running as a torrent for two or three months, it as quickly vanishes, leaving its channel to be covered with grass and flowers until the next eruption. Geology has now explained that this phenomenon is the natural consequence of an unusual amount of rainfall over the chalk hills of the district, into the porous substance of which the water sinks, to appear again after an interval in the form of springs, issuing from crevices at lower and perhaps distant levels; but old superstition regarded it as supernatural, and as an omen often of pestilence and scarcity, which are effects not unlikely to follow a great excess of rain. The Bourne did run this winter for nearly three months from Christmas-time.

2. Croydon, before the formation of the recent works, was, in relation to water supply and drainage, as most towns, in which well-water is found near the surface, have been at a certain stage of their growth; it had a well dug in almost every house-garden where water could be reached, and a cesspool for foul matters not very far from the well,—likely therefore to contaminate the earth around; then it had some ill-made drains remaining charged in general with foul matter, and it had very incomplete provision for the removal of subsoil and surface water. In Croydon, moreover, there existed the huge evil of a millpond, formed near the head of the Wandle by a dam built across the channel. This short-sighted attempt to obtain a profitable water-fall raised the level of the water above the dam nearly six feet, and thereby raised the level of the subsoil water

to the same height over about 50 acres of the low land of the town. After the dam was made, and until new earth was spread over the churchyard, graves could not be dug there two feet without exposing the water.

3. The unusual amount of rain during this season and the high atmospheric temperature, being circumstances calculated to quicken the decomposition of dead animal and vegetable substances, and so to augment malaria, would probably have produced at any rate an unusual amount of disease in Croydon, as has happened in other places; but coming when the earth was extensively broken up in connexion with new works not yet answering the intended purposes, the hurtful effect was aggravated.

4. The unavoidable diffusion, not connected with the season, of malaria, during the execution of the new works is next to be noticed. Among the proceedings were the general opening and emptying of cesspools, and the removal of the contents to other places: at first much of the fetid soil was spread on gardens and fields in and near the town. There was also the similarly offensive cleansing of old drains and of open ditches in connexion with the drains; and the great single work of the class was the removal of the dam which formed the extensive millpond above spoken of, by which change that pond and other ponds connected with it were drained previously to being filled up with sand and gravel. These works had to effect a great ultimate good, but for the time caused serious evil.

5. The site of Croydon having such peculiar relations to water as above described, there was needed there, in order to insure the degree of dryness required for the health and comfort of the inhabitants, a system of draining specially accommodated to the peculiarities—that is to say, capable of carrying away at times an unusually large quantity of water; but such a system has not yet been given.

6. On the contrary, a system in point of size exhibiting a strong contrast even to ordinary drains has been there introduced, namely, that of small stone-ware pipes, of which it has been deemed a merit that they were only large enough to carry away the house sullage and rain water from the roofs and yards,

which sullage being the portion left after evaporation, &c., of the water distributed to the houses from the public waterworks, is in small quantity. These pipes were intended to be impermeable, and to have air and water tight joinings, so that no foul air should escape from them, and no water from the earth around should enter them. To perform the remaining duty of carrying off the waters of the subsoil springs, of pond overflow, and of rain falling on the streets and open spaces, no sufficient general provision was made, and the means tried, as mentioned below, in two situations, have proved inadequate. Such waters, therefore, had to find their way to the river either by what remained of the old faulty drains, rendered now more unfit from being cut and interfered with by the new drains, or by overflow. The two exceptions referred to were, 1st, the brick culvert prepared to receive the Bourne water when that might appear, which culvert being pervious below, and beginning at an elevated level, allowed in part of its course the Bourne water to spread from it on both sides, flooding the small sewage pipes and the basements of houses near; and secondly, a pipe laid to drain the site of Laud's Pond, but which answered so ill, that at our visit to the spot, we saw an open ditch recently cut, allowing the escape towards the river of a copious stream of water which the pipe drain did not carry.

7. Under the circumstances of insufficient channels for drainage here described, two great evils not anticipated by the Board of Health arose. First, the joinings of the small stoneware pipes, which the theory assumed to be water-tight, were found in practice not to be so, for in various places the water of land-springs, rain, or the Bourne overflow, accumulating around them, found admission, and being added to what was already within, occupied the whole pipe, so as to produce not only serious obstruction to the onward passage of the sullage water, but total obstruction to the passage along the pipes of all foul air from sinks and closets, so that the ventilation of these in the direction of the water current as intended in the plan was rendered impossible. Such air, therefore, was necessarily left in or about the houses, adding very hurtfully to the malaria of the town.

8. The second unforeseen evil proceeding from the imperfect

joints of the pipes, and the entrance of water from around them, was, that the quantity of mixed sullage and water running along the pipes to the filter-house, where a strainer was placed intended to separate and retain all solid matters, and to allow only the liquid part of the sullage to reach the river, was much greater than the filter could admit, or than could afterwards pass by the pipes leading from the filter-house to the outfall lower down the river. The consequence was that much water loaded with the disgusting part of house sullage, which formerly remained in the cesspools, and was carted away at nights, was at first, during the whole day, visibly admitted to the river near the filter-house, and afterwards when the complaints of such contamination became loud from the inhabitants of the river banks, was admitted to the ditches of adjoining fields, and caused there a nuisance almost equally offensive. With larger sewer channels, or with a separate sufficient provision for carrying away subsoil water, the evils just described would have been altogether avoided.

9. But besides the now apparent unsuitableness of the small pipes to the peculiar state of Croydon during the last season, the Croydon experience has given evidence of other accidents causing diffusion of hurtful malaria, to which the pipe drains are liable merely because of their fragile nature and smallness. Very different and favourable results are described as being obtained in other places, as Tottenham, Rugby, &c.; but both kinds of occurrences have to be considered in judging of the new plan. In a book kept at the Town Hall of Croydon upwards of 50 stoppages of main-pipe sewers were recorded during the early months of their existence, while a still larger number of stoppages, not recorded, are known to have happened in the smaller or private house drains, occasioning altogether great annoyance, malarial nuisance, and expense. The causes of the obstructions were very various,—for instance, breakages of pipes from weight of incumbent earth, or from heavy carriages passing on the road over them, subsidence or bending of portions of the drain in yielding ground, arrest of bulky solids accidentally or maliciously introduced into the narrow channels, fibrous substances like hay, human hair, thread, pieces of cloth &c., sticking together with other sullage matter, and

gradually growing to the condition of complete plugs. Such events occurring in a place like Croydon, with an intelligent Local Board of chosen men eager to perform any amount of gratuitous service which promised advantage to their town, and who were near the Central Board in London, for easy conferences, prove that the desirable securities for the efficient performance of such works are not yet possessed; and further show that some of the anticipated advantages of the pipes have not been obtained, and some of the drawbacks connected with the employment of them had not been foreseen. It is true, also, that still in other localities failures and disappointments like those at Croydon have occurred, leading in some cases to the ultimate removal of the pipes and the readoption of the brick structures. In Leeds and Manchester, the combination of impermeable tubular drains for single buildings or small areas with larger channels of stronger construction, and suitable inclination for main sewers, is said to unite the advantages expected from the tube system with the security against accidents which belongs to the brick channels.

10. The assertion will not be disputed that the impurities of a town should not be drawn to one point until plans are completely matured for disposing of them, so that no new grievance shall arise. Yet, at Croydon, the existence of the general filter-house so near the town, the arrangements at that house, the emission of the foul residual water from it into the Wandle, and the daily irrigation with much unfiltered sullage of Waterman's Meadow, also near the town and near good houses of the suburb, are faults in this respect.

In conclusion, then, with regard to Croydon, it appears that the works required there are not yet complete; but there cannot be a doubt, that with a system of drainage suited to its peculiarities, accompanied by other subordinate arrangements, Croydon will be one of the most healthy, as it is already by its position and other natural advantages one of the most convenient and generally desirable residences near the great Metropolis.

The facts of which these paragraphs are a summary, belonging partly to the domain of medicine, and partly to that of engineering, are set forth in the separate Reports of the two members of the Commission.

Occurrences at Croydon proving Local Malaria.

I now proceed to narrate occurrences at Croydon, which prove that during the prevalence of the epidemic, there has been in the town, and in certain parts of it more than in others, noxious malaria, distinct from any slighter malaria, or epidemical influence, which may have pervaded the country generally. Had disease not sprung up under the circumstances described in the beginning of this Report, persons aware of the condition of the town, might well have doubted whether foul air could at all produce disease, and whether sanitary measures of purification could truly be of value.

1. Dr. Chalmers, a physician who had served more than 20 years in India, where I had the pleasure of seeing him treating the diseases of that country, and among these having to study the malarial fevers of the marshes, jungles, and shores, had, since his return, resided and practised for 22 years in Croydon. In December last he fell ill of the fever, as did at the same time one of his domestic servants. He narrowly escaped with life, and he has since been at Brighton, to which, when in extremity, he was removed. He gives me by letter an account of his case. His house was close to Laud's Pond. "This pond," he says, "is one of the chief heads of the Wandle river; when closed by a sluice during the night, it would become from four to five feet deeper; into this body of water the whole sullage from the neighbouring parts of the town had of late years emptied itself, and around it were the privies of the houses on its banks. Hence an immense accumulation of filth formed its bottom, from whence, when the water had run out or the springs were low, the most offensive effluvia emanated. This pond was filled up, without previous cleansing, by the Sanitary Board, with sand, gravel, and rubbish. For some time the site remained tolerably dry; but in October, I think, on digging a foundation for a new gasometer, the springs were opened, and in one night the whole surface of the original site was covered with water a foot or two deep; the water, forcing its way up through the mass of accumulated ordure or offensive animal and vegetable matter, on reaching the surface brought with it, doubtless, a solution of the elements of putrescency, vitiating

the atmosphere around. About this time I began to feel lassitude and general malaise, and loss of usual vigour of body and mind. These signs of disease approaching lasted for nearly three weeks, with occasional chills, and on the 3rd of January I was laid prostrate." He goes on to say, that on the 8th, alarming symptoms came, and his medical friend from London, Dr. Hughes of Guy's Hospital, recommended immediate removal from the atmosphere of Croydon. On the 10th he was conveyed to Brighton, where he recovered with singular rapidity. He says, "From the moment I reached the influence of the sea air I was able to sit up, and with assistance could walk to the carriage waiting for me, although in Croydon I could not stand. The prominent symptoms of the disease were a low erysipelatous, tumid state of the mouth, fauces, and pharynx, terminating in foul ulcers; thirst urgent, pulse feeble and irregular, emaciation extreme." He continues: "The same causes I believe had existence in the higher parts of the town, owing to the disturbance of the old cesspools and the quantity of rain. I have only to add, that though typhoid and typhus fevers were scarcely ever entirely absent in the old town and the part adjoining, well named Bog Island, during the 22 years of my residence, I do not recollect any epidemic similar to this fever."

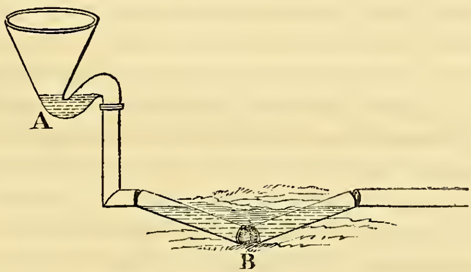
2. One of the medical practitioners of Croydon, living at Southend, in conversation with me, related that in the middle of the night he awoke in great uneasiness, and perceived immediately that the cause was a most offensive smell in the room, like that of drains: it made him sick. His wife also awoke, and immediately complained of the intolerable smell; it soon caused her to vomit, and this disturbance proved to be the commencement of an attack of the prevailing illness, which confined her for six weeks. Two other persons in the house had fever. There were near the house two open gully-holes of an old drain, from which, at irregular times, and suddenly, most offensive bursts of stench issued. The new drains of the house were totally obstructed for weeks. The effluvium may have been from the old drain, or it may have been from the new, in the way proved to have occurred in the next case here related. Other house drains were stopped in the same neighbourhood; two of them in the houses of medical men, in whose families

also fever broke out. Fever cases were numerous in the whole locality.

3. Mr. Grattan, solicitor, states that the drains of his house, though allowing water to pass away readily, often sent back strong gusts, sometimes audible, of fetid air, when water was poured into a closet or sink. On one occasion the experiment was purposely made in three such places in succession, and the foul air issued from every one. His children, before the establishment of the new drains, had been remarkably healthy, but after the change they became sickly, being affected with indigestion and frequent diarrhœa. On removal from home into other air they speedily recovered, but on returning after a few weeks, they again sickened. A second removal again restored them, but a second return was again unfavourable. He then left the house. He was himself frequently affected as the children had been.

This sudden emission of foul gas through the syphon-trap, supposed to be secure, of a drain into which water readily enters and passes along, being somewhat paradoxical, has by many persons not been understood and so not guarded against. The explanation is this: If into the neck of a bottle half full of water the stalk of a funnel be passed and some water be poured into the funnel, then just the same bulk of air must escape from the bottle, around the stalk of the funnel, as there is of water entering; the air being pressed out or displaced by the descending water. If the funnel stalk be then enlarged by covering so as to fill the neck of the bottle like a cork, the descent of the water is either totally obstructed by the resisting air below, or the water descends only gradually as bubbles of air rise up through it. The air thus compressed in an air-tight cavity by the weight of water seeking to occupy its place would escape by any small opening which it might find, just as coal-gas escapes from a compression made at the central gas-work, through the apertures of gas-burners. In a sink or closet, with a drain entirely stopped by any solid plug, it follows that the air shut up between the entrance and the stoppage is situated like the air in the bottle described above, and must be compressed or be driven out by water entering; and the same result may happen if the solid stoppage be only partial, that is to say, such as will allow water to pass by, only less quickly than it enters above; or if the stoppage be not by a solid obstruction at all, but merely by water detained in a part of the drain which either by original fault of the laying down, or by subsequent accidental subsidence in yielding earth, has sunk below the proper line of the drain, as represented in the accompanying diagram at B.

Fig. 21.



In the last case it is evident that the syphon-trap of the closet pan at A, shutting in the foul air between A and B, has less depth or resisting column of water than the accidental syphon-trap at B, and that air compressed between these will more easily force its way at A into the closet and house than at B along the drain towards the outfall. It is clear, moreover, that any one of the 50 stoppages of main drains recorded in the book at the Town Hall of Croydon did for the time convert all the sewers and house-drains (if impermeable as the Board of Health originally intended) between it and the houses into one great closed vessel of foul gas, from which every gallon of water that entered quickly through any one of the closets or sinks would drive out nearly an equal volume of air at the weakest or least resisting trap or traps of the set. And thus any person, without being aware of the fact, might be forcing foul air into a neighbour's house, and a shower of rain might at once empty into many houses of a neighbourhood the confined air of many drains.

The escape of confined foul gas, as above explained, from the syphon-traps of closets and sinks has evidently been common in

Croydon. Most of the medical men had believed it frequent, without perhaps thinking of the exact nature of the accident. Thus Mr. Bottomley, in his written communication to the Commissioners, used these words: "The escape of noxious gases from the small tubes into the houses, keeping up a foul unhealthy state of the atmosphere in these houses, thereby much retarding the recovery of the sick, and keeping alive the danger of fresh outbreaks." And Mr. Berney, in speaking to me on the subject, said he believed the occurrence to be common; that many persons had complained of such smells; and he spoke particularly of a house where a young gentleman was then (on 13th April) seriously ill of the fever, in which house such complaints had repeatedly been made. He mentioned also the case of a lady who, on asserting the fact of such escape, was told by some one that it could not be, and she desired the objector to try the experiment by pouring a bucket of water at once into the place as she had seen done.

4. In the school of the Society of Friends, of size to accommodate 150 children, there occurred upwards of 30 cases of fever and of bowel disturbance, and there happened two deaths, one of which was that of the superintendent, a healthy man of 40, and the other that of an assistant. The house was remarkably clean, and altogether well managed, as would be expected from such occupants. It is built on an elevated healthful site. There had been some, but not much, complaint of the smell from the closets, and no cause of the outbreak was clearly indicated. The intelligent Committee of Management, anxious to have all attainable security, determined to ventilate their system of drains. They did this by a pipe rising from the highest part of the drain to above the house roof, through which pipe effluvium formed below, instead of entering the closets, would be dissipated in the open air. One of the teachers lately ascended to the roof, and holding his face over the opening of the pipe, inhaled some of the escaping air; it was so offensive as to make him sick; he could not afterwards that day take dinner, and he remained much indisposed all the evening. This occurrence proves that, although the drains allow the sullage to pass away, there is old filth retained somewhere in connexion with them. It may be as deposit in

them, which does not obstruct them quite; or the air may be retained in them to putrefy, by a subsidence of drain somewhere towards the outfall, as explained above, forming the accidental syphon-trap; or the sewer lower down may be choked by the admission of subsoil water; or the foul air from pipes in the lower part of the town may, because specifically light, be forced to a higher part. Such foul air as here spoken of escaping, even in small quantity, could not but influence unfavourably the health of inmates. But whatever its origin the ventilating tube now put up prevents the diffusion of it in the house.

An important difference between the old sewers with gully-holes, allowing entrance of atmospheric air to dilute the drain-effluvium, and the pipe sewers without ventilation, is, that in the latter the effluvium being unmixed or concentrated, is much more noxious.

5. In the Barrack-field there is a beer-shop, where, as described in Mr. Grainger's Report, the old drain from the privy was cut by the new drain, and the work being left incomplete, the house-yard was flooded with the sullage for many weeks. There were 15 inhabitants in the house, and they were all attacked, first with diarrhœa, and then 8 of them with fever. It is not out of place here to remark that the malaria which thus affected seriously every one of the 15 persons in this house was not an epidemic influence of Kent or Surrey, but a local cause in this flooded yard; and again, that the stench which affected the persons sleeping in their beds, as above spoken of, was not of the region, but almost of their room; and the malaria which attacked Dr. Chalmers and his servant was not of Kent, or even of Croydon, but of the border of Laud's Pond.

6. As Mr. Page and I were passing through the old town, making examinations, a butcher residing there, Mr. Burrell, came up to say that of the row of houses opposite to him, all of which were connected with the new drains, 12 had the connexion of their sinks on the outside of the house wall, so that no return of the foul air from the sink could readily enter the house, while other 12 had the openings within the wall, so that any return of foul air would be under the roof; he added

that in the first-named 12 houses no fever had appeared, whilst in the others there had been 16 cases. Future inquiry found that the statement was exaggerated, but that the effect of the difference of arrangement was very marked.

7. Many of the medical men have pointedly observed that while common epidemics attack first and chiefly the lower classes of the inhabitants, who are badly lodged, clothed, and fed,—as the typhoid fevers occurring occasionally in Croydon in former years have always done,—the present epidemic attacked chiefly persons of the middle and higher classes, or those living in superior houses. Dr. Sutherland and others remarked upon this, that the waterclosets of the superior houses were situated within the houses, while those of the inferior were generally outside and at some distance. Then the nuisance from the disturbance of cesspool clearing was much greater in connexion with the larger houses than with the smaller. In confirmation of this view comes an observation of Mr. Hubbert, one of the medical officers at Croydon, who, in his written communication to us, says: "A remarkable fact obtains in the High Street of the town (where the fever prevailed much): several houses, with large families resident, have had no communication with the drainage system; they have not had their premises or cesspools interfered with at all, and up to the present time no disease has appeared in their establishments." The Military Barracks, also unfavourably placed, but not connected with the new drains, had no fever.

8. Then, on the other hand, there are some remarkable instances of large houses connected with the new drains which escaped the epidemic almost entirely, such are, 1st, the Workhouse; but in it the privies are not within the house, and are peculiar in having beneath the seats iron troughs, which a man is employed to clear out perfectly by flushing several times in the day. 2nd, the Trinity Hospital, in which 60 aged men and women dwell, situated in the middle of the region which suffered most; but this also has its closets away from the dwelling-house. At the East India College, at Addiscombe, not far from Croydon, there has been no case of fever, but slight diarrhœa has been common: it had no connexion with the new drains up to November.

9. It is now to be mentioned that the fever has appeared in several good houses standing apart from the town of Croydon on the east and north sides, and which have no connexion with the sewers. These lie in the direction in which the prevailing wind blew from the central regions of impurity, where the fever prevailed most. Few detached houses were influenced on the other side towards which the wind blew seldomer.

The concentration or non-diffusion with which malaria of nearly the specific gravity of the atmosphere can be carried along by the wind is a fact by many not fully considered. People see how quickly the warm breath is diffused, or the steam from an engine chimney, or the smoke of a common chimney, or that of a cannon fired, and not reflecting that the air in some of these is escaping from compression, and therefore suddenly dilates or scatters itself, and that in all it is hot, and so is tending to diffuse itself upwards, they assume that a cold malaria must comport itself in the same manner; but it does not. The common experiment of extinguishing a candle on the other side of a room many times in succession by what may be called a bullet of air shot at it from an air-popgun, shows how far air of the same heat and density as the atmosphere can travel in it with little mixing, and how the sudden and transient smells of which persons are sometimes sensible, and the unsuspected contagion or malaria of smallpox, measles, &c., may travel in the same way.

10. In some instances the fever seemed to be carried or communicated by contagion or infection from person to person, as where six persons were infected in a house at Coulsdon, four miles from Croydon, the first of the six being a young woman who went thither from Croydon with the fever already upon her; but none of the medical men who witnessed the occurrences at Croydon have expressed a decided opinion upon the subject. Some years ago in regard to this question medical men generally believed that any particular fever was in its nature either always contagious or never contagious; but such opinion has of late been modified. In an addition to this Report,* I refer to modern discoveries in science as illustrating the origin and nature of fever and epidemics generally, and I con-

* Printed at page 63 of the present volume.

sider the subject of contagion, and the effect of diluting aërial poisons by ventilation to lessen their intensity or virulence, and to diminish or prevent the spread of epidemic disease.

11. The medical men of Croydon have remarked that the fever has differed from the common continued fever of this country in having more than usual of the gastric or bowel irritations, diarrhœa, flux of blood, ulceration, and other symptoms which arise when the active malaria has contained more than usual of impurity of animal origin. Mr. Hubbert speaks of the sloughing abscesses and boils which occasionally appeared, and adds, the "phases of the disease seemed to indicate the absorption of animal poison." On this part of the subject, also, I treat in the general review of the subject of fever.

12. A strong fact, pointing to local malaria, has been the sudden and great relief generally obtained by affected persons who left the town for a different air. The cases of Dr. Chalmers and of Mr. Grattan's family are striking instances. In speaking on this subject to different inhabitants, almost all seemed to know remarkable cases in confirmation. Mr. Berney mentioned several; but named one gentleman, a friend of his, where the change did not avail: the reason, however, was ultimately discovered to be that, during the bowel irritation which accompanied the fever, an ulcer had formed in the lining membrane, and did not afterwards heal.

13. Confirmatory of the view here taken, that the Croydon epidemic has depended chiefly on causes existing within the town, and not on a vague epidemical influence, such as in former times of less knowledge was assigned as the cause of all epidemical outbreaks, there are many facts set forth in the elaborate and able Report on the late events in Croydon, drawn up by Mr. Grainger, Chief Medical Inspector of the General Board of Health, and also in the very able Report of Mr. Simon, Officer of Health to the City of London, and in the communications of the enlightened body of medical men who, during the epidemic, have been labouring at Croydon by their professional and other services to mitigate the evil. Mr. Grainger, says, for instance, after speaking of the cesspools, old drains, imprudent spread of night-soil, the filter-house, &c.—"But independently

of these external causes inducing a general malaria, I attach great importance to the effluvia which, in so many instances, according both to the medical evidence and my own inquiries, have existed in the interior or in the immediate proximity of the houses, a class of emanations which, operating on the inmates chiefly and constantly, are much more injurious than even more powerful effluvia discharged into the open air of streets, and only occasionally acting in a concentrated form."

It is to be regretted that the General Board of Health, after, in one part of their "Minutes of Information," at page 100, showing at length the very grave importance of ventilation of sewers, and recommending it to be done by pipes rising into the air, should in another part (at page 145) direct the ventilation to be effected along the sewers towards the outfall, to do which in many cases, as under the late circumstances of Croydon, is impossible. This seems to have led to failure in an important part of the work. My colleague, Mr. Page, in his account of the works, will have to speak of this in detail.

In concluding this part of my Report, I may observe that, although in Croydon, now, things for the time may appear to be going on well, since the rains and the overflow of the Bourne have ceased, and there are no longer cesspools in the houses or gardens (this, however, at some cost as yet to parties living near the filter-house or on the banks of the river), and there is everywhere an abundant supply of good water, and most of the cases of defect or faulty placing of the drain pipes may have been detected and mended,—changes which during favourable weather will secure a great improvement on the former state of the town,—still there should not be delay in proceeding with works which shall remove radically or for ever the evils that have recently existed.

THE GAS EXPLOSION IN ALBANY STREET, REGENT'S PARK.

(Referred to at p. 188.)

To the Editor of the Times.

Sir,—A destructive accident of a new kind or degree becomes often a very valuable public lesson by attracting attention to a subject previously ill understood, so that while the prejudices, both of those who lived in false security, and of those who had groundless fears, are corrected, all persons come to learn that there are easy means for avoiding like accidents for the future. The late gas-explosion in Albany Street, Regent's Park—the most disastrous perhaps, which has taken place since gas-lights have been used, by which one house was wholly demolished, and all the houses around were more or less damaged—appears to be an occurrence of this kind. At the inquest held on the body of a servant who was killed, parties interested in gas-works wished to make it appear that gas could not have been the explosive agent, but that gunpowder or gun-cotton must have been in the house. It was of consequence that no doubt should remain on this point. I was present at the inquest, by the request of the coroner, to explain to the jury the bearing on the event of certain principles of chemistry and mechanics; but questions having been put to me since then which prove that the public mind still needs information on the subject, I state again, in the following form, what I deem to be important:—

Since air-cushions have come into use, and we see heavy weights supported on them, or, more strictly speaking, supported on the bulky resisting substance of the air shut up within them, persons are not surprised to learn that air has other qualities of common substance as well as bulk—weight, for instance, as proved when a bag containing one cubic foot of common air is emptied by a condensing pump into the copper ball of an air-gun, and the ball then weighs nearly an ounce and a quarter more than before. It is but a step beyond this for them to learn that there are different kinds of air or gas; that the air, for instance, which issues from fermenting beer or wine—called by chemists carbonic acid gas, and popularly called choke-damp, because any animal immersed in it dies—is about twice as heavy, bulk for bulk, as common atmospheric air, and is found accordingly streaming over the edge of fermenting vats towards the floor, nearly as water would; and then, again, to learn that the air with which a balloon is filled, whether pure hydrogen-gas or coal-gas (which is hydrogen-gas with some coal or carbon dissolved in it), is so much lighter than common air, that a balloon charged with it is lifted into the sky, carrying its load of passengers just as a small bag or balloon filled with oil would be lifted in a mass of water; the reason in both cases being that the surrounding fluid is much heavier, bulk for bulk, than the enclosed fluid. But the difference of air from air is still more strikingly seen when the coal-gas from the balloon, if transferred to a gas-holder, and then caused to jet from a small opening into the atmosphere, may there be kindled to become our common gas-light, continuing to burn just so long as fresh gas and fresh atmospheric air are allowed to come together. This kind of information has now advanced so far that most educated persons know that the form of air or gas is one of the three forms, solid, liquid, and aëriform, which all the elementary substances in nature readily assume, according chiefly to the amount of heat among their particles, and to their being united or not with one another; just as we see the substance of water existing in the three states of solid ice, or liquid water, or aëriform steam, according as it is differently heated or compressed; and, lastly when it is known that when chemical union takes place among different substances with intense mutual action of the particles, the phenomenon of increased heat, often to the extent of ignition is produced, as when certain proportions of the solid sulphur and iron, placed together and warmed, begin to ignite with strong ignition, forming the new substance, unlike to either, called pyrites; or similarly, when oxygen and hydrogen, in the form of airs, being brought together in certain proportions as mixing jets, and being heated by momentary contact of a light, combine, giving the phenomenon of a gas-flame, and the product is found to be the commonest of all substances—water.

Now, such is the relation of ordinary coal-gas to atmospheric air, that if the lighted gas be allowed to issue uniformly, and to mingle always with a sufficient portion of fresh atmospheric air, it burns with a safe and steady flame, combining gradually with the oxygen of the air; but if before being kindled any considerable quantity of the gas be allowed to issue and to mix completely with just ten times its volume of atmospheric air, on a light being then applied the whole mixed mass kindles at once as a flash, like gunpowder, and dilates with violent explosive force. The strength of such explosions is shown in coal-mine accidents, where sometimes more than one hundred men at one time have been destroyed, and bodies of men and horses have been thrown out of a shaft like bullets from a gun. It may be experimentally exhibited by filling a bag with the required proportions of gas and air, and then blowing soap-bubbles with air from the bag, each of which bubbles, when set free and touched in its ascent by the flame of a candle, explodes like a pistol-shot. The degree of the expansion of the air when thus fired, and which is caused by the sudden heat of the chemical action, is held to be at leastten fold; or such that one cubic foot, which weighs something more than an ounce, becomes for the time more than ten feet, while an ounce of gunpowder during explosion is known to expand only to about three-fourths of one foot of gaseous matter. It is to be remarked, however, that gunpowder shows its prodigious force, not when allowed to explode in a wide and open space, but when confined to the bottom of a gun-barrel; and there, as it does not expand like these airs from a previous state of air only ten times less bulky than at the final explosion, but from the previous state of a solid powder, which is about eight hundred times less bulky than the gases evolved from it during the explosion, the commencing explosive force of gunpowder is greater than that of the mixed gases, nearly as 800 to 10, or 80 to 1, on every square inch of any surface opposing it.

With the knowledge that coal-gas may cause explosion, few persons would at first suppose that it could be at all safely admitted into dwelling-houses, yet the experience, now of many years, has proved that the accidents to life and property from it are many fewer and less in proportion than those from common lamps and candles, and that what may be called the natural dangers of gas can, with more certainty, be guarded against than those of lamps and candles. Hence fire-insurance companies in many cases prefer the risks of gas to those of other means of lighting. This explains why the gas-light is now becoming almost universal, as seen in street illumination everywhere, in shops, in places of public assembly, as churches, Houses of Parliament, &c., and in many towns, as in Edinburgh, where it is used in almost every house. The advantages of gas over other lights are, that it is very cheap as well as brilliant; that it throws out no sparks, never wants snuffing, is always ready, is placed in a chosen, safe situation, from which it is never moved, needs no great skill in lamp-trimmers, and can be easily varied in strength as wanted.

The reasons why gas-explosions in houses are so rare, and with a few exceptions have been so harmless, will be understood from the considerations now to follow :—

In the case of gunpowder, which consists of fixed proportions of nitre, charcoal, and sulphur, intimately blended, all the things necessary to the explosion are present in the powder itself, waiting only the spark which is to inflame them, and the smallest spark can inflame the largest magazine. The phenomenon consists essentially in the fact, that certain chemical elements, joined together in one way to form solid gunpowder, by being heated are suddenly allowed to enter into new combinations which assume the gaseous form; and such explosion may take place under water or in a vacuum as readily as in the air. But far different is the case of coal-gas considered as an explosive agent. The gas itself, like the charcoal of gunpowder, is only one of the elements of a fulminating mass, and can no more explode alone than the contents of a coal cellar can. Before it can burn at all, every particle or measure of it must find somewhere, and mix perfectly with, two particles or measures of oxygen gas. A lighted taper plunged into mere coal-gas, instead of exploding the gas, is itself instantly extinguished by it. Now, the coal-gas of our lights obtains the needed oxygen from the atmospheric air into which it jets; and as atmospheric air everywhere consists of one proportion or measure of oxygen mixed with four of nitrogen, there must be present exactly ten measures of atmospheric air—as stated in a former paragraph—for every measure of coal-gas that is to be wholly burned; then, even if these required proportions are present in any room or place, but not duly mixed, only such parts of each can burn as come together in the necessary proportions, while the excess of either, wherever found, instead of contributing to the combustion, absorbs part of the heat from what does burn, and by lowering the temperature of that, renders the explosion both so much weaker and slower as to be comparatively harmless. This is the history of the vast majority of the gas accidents which have occurred. To speak with precision on the subject of the proportions, it is to be stated that while one measure of gas to ten of air gives the strongest explosion, a slight variation in either direction singularly weakens it, and if the gas present be either less than one-fifteenth part of the whole or more than one-fifth part, there can be no explosion at all. In other words, if into a vessel holding eleven pints of air, one pint of coal-gas were introduced in lieu of a pint of air expelled, there would be the strongest effect; but if the quantity of gas were either increased to two pints or more, or were lessened to below three-quarters of a pint, there could be no explosion at all.

Having these facts present to the mind, and the additional fact that a common gas-burner allows only five cubic feet of gas to pass per hour, while a small sitting-room contains in it 2,000 cubic feet of common air, one sees,—first, that unless the gas proceed from broken pipes, as was the case in the recent explosion, a great accumulation of it is most unlikely to occur in an inhabited house; secondly, that there is little chance, even if the exploding proportions were in the same room, that they would be uniformly mixed as required for the explosion; for the coal-gas being light, or balloon gas, it first mounts to the ceiling, comparatively little mixed with the air of the room, and for a time floats there over the common air, like oil on water, and is only slowly diffused according to the law which insures at last a uniform diffusion of all communicating gases; thirdly, while the mixture were in progress the explosive proportions might be confined to one level or stratum, and generally high up away from persons carrying candles; fourthly, coal-gas escaping into a room, being very light, readily passes away from it again by any openings near the ceiling, as at the tops of the windows and doors, and most certainly of all, into the chimney, where the new chimney ventilating valve is in use; fifthly, in cases of the escape of gas, long before the proportions required for the weakest explosion have accumulated, the smell is so strong that persons are fully warned and can withdraw lights, and open windows to remove all danger. A man would be deemed insane who deliberately applied a burning candle to muslin curtains or gunpowder, which he could see, and surely, henceforth, a man will be as little likely to carry a candle into explosive gas which he distinctly smells.

The series of faults committed to bring about the Albany-street explosion was extraordinary indeed.

1. The gas-meter with its pipes and cock—a delicate apparatus, likely to be damaged by a rough touch—was placed in an enclosed dark space under the window-shelf, which was made to serve also as the receptacle for the numerous heavy window-shutters pushed in and dragged out every morning and evening.

2. It was not a careful person of the shop who managed the window-shutters, but a thoughtless boy, who came night and morning for that purpose alone.

3. It had been often observed that gas was escaping, and examinations and repairs about the meter were frequent; yet the hazardous arrangement remained unchanged.

4. When at last, on the night of the catastrophe, the boy, as was to be expected, at some time struck the meter forcibly with a shutter, and thereby instantly extinguished all the light in the shop, no natural alarm was felt by the persons in the shop; but his account that the shutter had accidentally touched the main cock, and so turned off the gas, was admitted as complete. The small cocks at the three burners were then shut, and he was allowed to depart. He had in reality left a leak at the meter by breaking the main cock and pipe, and in one hour and twenty minutes the shop was filled with explosive mixture.

5. Smell of gas was felt almost immediately near the shop-door, and before long at the top of the stairs; and when Mr. Loten and the shop-woman were called down to supper in the back-parlour, which communicated by a door with the

shop, the smell was so strong that Mr. Loten, taking a candle in his hand, went towards the shop to examine it. He had opened the door just enough to let the air of the shop touch the candle, when the explosion occurred. He and his companion were blown with part of the wall of the house into the back-yard, both much burned, but not killed. A maid-servant who was in the passage near the front door, was dashed across the street, and killed on the railings there.

6. The shop with its many lights had no fire-place to favour ventilation, and the doors had been edged with leather to make them close. Then the complete mixture of escaping gas with the air of the shop was favoured by the fact that the gas did not escape from the burners high up, but entered the shop low down and through the chinks of the shutter-box.

From what has now been said it will appear that the means of safety for persons using gas in their houses are—

1. To have the apparatus made and fixed by competent workmen.

2. If any leak be perceived by the smell, to have it promptly attended to, and immediately to open doors or windows to prevent accumulation.

3. On no account to carry a lighted candle to where there is strong smell of gas.

4. To have the room or rooms in which gas is burnt ventilated from near the ceiling. The balanced chimney-valve, which I proposed some years ago as a means of maintaining a healthy state of inhabited rooms generally, and which, having been favourably mentioned in a clause added to the Metropolitan Building Act expressly to direct the mode of fixing it, is already extensively used, would make it almost impossible for a dangerous accumulation to take place, even if the burner-cocks were purposely left open; and wherever gas is used in an inhabited place, this valve is not more important as a security against explosion than it is to guard inmates against the deleterious effects of breathing the burnt air of common gas illumination or of any other. There is no patent right for the valve, and an adroit workman anywhere may make it.

With these precautions coal-gas is in a majority of cases, not only the most beautiful, convenient, and cheap means of lighting, but, as shown by past experience, rendered still more assuring by the explanations of scientific men, is also on the whole the safest; and it may therefore be regarded as one of the precious boons which advancing science has bestowed of late on the human kind.

I am, Sir, &c.

Bedford-square, Sept. 1848.

EXTRACT FROM A REPORT ON THE FEVERS WHICH HAD PREVAILED IN EDINBURGH AND GLASGOW, MADE TO THE POOR LAW BOARD BY DR. ARNOTT, IN THE YEAR 1840, AFTER A VISIT OF INSPECTION.

(Referred to at p. 69.)

IT gives remarkable simplicity to all inquiries respecting health, to know that among the things and influences around man on earth, in regard to which he can exercise control, there are only four which he needs to obtain, and two which he needs to avoid, that he may have uninterrupted health for as long as the human constitution is formed to last; in other words, that only by some want or misuse in regard to four requisites, or by the direct agency of two kinds of noxious agency, can his health be impaired or his life be shortened.

This knowledge gives a singular interest to the contemplation of the past history and present condition of men and societies, by explaining innumerable facts which have much affected their welfare, and by suggesting important measures for securing that welfare in time to come. It explains, for instance, why certain climates, situations, occupations, &c., have been more or less healthful than others; and why, in respect to healthiness, great changes have arisen in climates, situations, occupations, &c., both from what may be called accidental causes, and from the efforts of intelligent minds, following past experience in the pursuit of good. And it must be such knowledge or general principles which shall account for any present or future local prevalence of disease, and shall prescribe the fittest means for combating the evil. Then to such knowledge must reference be made when questions are to be answered like those lately proposed, through the Poor Law Commissioners, to medical men and magistrates respecting the sources and means of removing serious disease in certain localities in England and Scotland. I had the honour to be requested to aid in this inquiry in relation to the fevers which have prevailed in Edinburgh and Glasgow, and the present short statement is the sum of what I have seen and thought:—

The four things to be obtained, above referred to, are fit *air*, *temperature*, *aliment*, and *exercise* * of the bodily and mental faculties: the two things to be avoided are *violence* and *poisons*. For the sake of easy inspection, the whole six are set forth in the following table, in which also are placed, in a second and third columns, names of deficiency and excess in relation to the four necessaries.

Any person who has not already reviewed this subject in a general manner will be struck to find how large a proportion of the diseases known to him are arranged, even in popular apprehension, under single particulars or simple combinations of the particulars above noted as their causes. Need we recall, for instance, how many of the diseases of England are known to proceed from fault in temperature alone, as our winter colds, catarrhs, quinsies, pleurisies, croups, rheumatisms, &c.—that others spring from insufficient or bad food among the poor, and from surfeit or too stimulating food among the rich—others again from crowded and ill-ventilated apartments among the manufacturing labourers and such sedentary persons,—and so forth? And as in the present day persons do not look for preternatural or miraculous occurrences among the phenomena of living bodies any more than among those of the earth itself or of the heavenly bodies; so every disease is believed to be an occurrence perfectly in the course of nature, and a necessary consequence, therefore, of certain preceding occurrences which are said to have brought or caused it, and which occurrences may be studied and analyzed.

Some of the causes when in slight degrees act so slowly as to be long unperceived by the vulgar, as in the instances of insufficient exercise, faulty ventilation of the dwellings, certain

* The explanation of why *four* things are wanted is given in the comparison between the steam-engine and the animal frame made at page 67.

kinds of food and drink, &c.; and, indeed, it is only of late, since statistical records have been brought to bear on the subject, and have shown that in various conditions of air, temperature, food, and exercise, the average duration of life in societies is affected to the extent of some known proportion, that even the best-informed persons can be said to estimate with tolerable accuracy the influence on health of many of the circumstances.

The Four Necessaries.

In fit Kind and Degree.	In Deficiency.	In Excess.
1. Air	Suffocation . . . . Unchanged or foul Air	Excess of Oxygen, from hurried breathing.
2. Temperature . .	Cold (intense) . . .	Heat (intense).
3. Aliment:—		
Food	Hunger.	Gluttony or Surfeit.
Drink . . .	Thirst	Swilling bland fluids.
4. Exercise:—		
Of the body . .	Inaction	Fatigue or Exhaustion.
	or	
Of the mind . .	Ennui	Want of Sleep.
	Certain depressing passions, as fear, sorrow, &c.	Certain exciting passions, as anger, jealousy, &c.
Of the mixed social aptitudes.	Solitude	Social Debauchery.

The Two kinds of Noxious Agents.

1. Violence:—
   Wounds, Fractures, Dislocations.
   Burns, Lightning, &c.

2. Poisons:—
   Animal, Mineral, Vegetable.
   Certain of these, such as *alcohol* in its various forms, opium, tobacco, &c., which in large quantities kill instantly, when they are taken in very moderate quantity can be borne with apparent impunity, and are sometimes classed as articles of sustenance, or they may be medicinal, but if taken beyond such moderation, they become to the majority of men destructive slow poisons.
   Contagions,—as of plague, small-pox, and measles.
   Malaria of measles, thickets, and of filth.

But all can understand that as different breeds of sheep, cattle, horses, &c., are produced and change strikingly according to the pasture, climate, and treatment given them, so does the human constitution slowly become modified by kindred circumstances to conditions not deemed disease, but called temperaments and varieties, compatible with health and long life.

Of the causes of disease set down in the table, the two last noted, viz., contagions and malaria, as might be expected from many of them being unperceived by sight or by any other human sense, and being therefore known to exist only by their effects, have been more lately known and less understood than most of the others. And even at the present day the inhabitants of New York might see yellow fever destroying its thousands among them, and yet remain in doubt whether it had been imported from elsewhere, or had been generated among themselves, and whether it were passing from one person to another, or were received by all who had it from the soil or the air of the place.

The men of the present time, however, by being able to consult and to compare the records of many ages and of many countries, have ascertained in relation to this subject very important facts, such as were referred to in a former report made to the Poor Law Commissioners on the fevers, &c. of London, published in the volume for 1838 of their printed Reports. Among these facts are the following: That in many situations on earth where there is going on the putrefaction or decomposition of animal and vegetable substances, and often in proportion to the amount of this, there arises into the air an exhalation now called malaria, which produces the state called fever. In hot countries, with marshy or thickly-wooded localities, the fevers which spring up are named the bilious remittent, the jungle, and the yellow fever; and in situations where men congregate and human filth is added, the fever called plague appears, as in Egypt and elsewhere, around the Mediterranean. In colder climates there are the intermittent marsh fevers or agues; and where human filth abounds, there spring up the fevers called typhus, putrid, scarlet, erysipelas, gaol fever, ship fevers, &c. And it is ascertained that many of these, when once generated in a single case, spread afterwards rapidly from person to person by contagion or infection, as it is called. Then the careful examination of the recorded facts seems to show that how much soever persons may be rendered liable or predisposed to any of these fevers, by cold, hunger, fatigue, debauchery, mental depression, or other of the causes of disturbed health set forth in the above table, they no more can have the fevers, if the aërial poisons of original generating filth or a subsequent contagion be withheld, than gunpowder can be made by mixing its other ingredients while the sulphur is wanting.

If, after the influence of the malaria from filth had been noted, the question had been put in England, Where might we expect to see the effects of it most strikingly manifested? the answer, until about 60 years ago, must have been, "In the prisons of the kingdom." In proof, let the appalling narration of the philanthropic Howard be consulted, the bent of whose mind carried him into those abodes of misery, that he might witness the facts, and afterwards labour, as he did with success, to lessen the evils. Wherever he found a crowded prison, there also, almost certainly, he found that gaol fever was frequent, and that the source often was the felon's dungeon, which, still more than other parts, was without ventilation, without drains or other means of cleanliness, with little light, and which consequently remained in the most noisome condition. The gaolers in many instances were unwilling to accompany him into some of the cells, alleging the danger of catching the fever, of which other gaolers had died. And he relates that often after such visits his clothes were so impregnated with the disgusting effluvia of the place that he could not bear to travel in a close post-chaise, but had, even in rainy weather, to pass from town to town on horseback. Then he could not use the book in which, while in the cell, he noted what he saw, until after it had been heated and aired before a fire; and even the phial of vinegar which he used to smell at as a security to him, quickly became so offensive that he had to change it frequently. He states further, that in his time (about the year 1780), and in preceding times, when many more malefactors than now were executed every year, a still greater number of the prisoners usually died of the fever than by the gibbet, and among them, sad to relate, were not a few whom misfortune alone had placed there by rendering them unable to pay all their debts: such persons might be truly said to rot in gaol. Then the disease often spread extensively in neighbourhoods, carried thither by prisoners after their release. And in the first fleet which sailed from England in the American war, 2,000 people died of fever, carried into ill-ventilated ships by persons taken as sailors from the prisons. But perhaps the most striking occurrences of this class were such as "the Black Assizes at Oxford," where prisoners from the dungeon brought for trial into the crowded and ill-ventilated court-house, so poisoned the atmosphere, that most of the persons present were quickly affected, and before 40 hours had elapsed, the judge, the sheriff, and about 300 others were dead. Then this was far from being a singular instance of the kind: Howard, at page 9 of his work, refers to several others, in which the judges fell sacrifices.—While Mr. Howard knew England only, he believed that gaol-fever sprung from impurity alone, but after he had seen equal filth in continental prisons without the fever, he questioned whether, owing to English habits, the change from liberty to confinement, and from the full diet to prison fare, might not affect his countrymen more than their neighbours. His difficulty would probably have been removed had he been fully aware of the influence of climate above referred to, on diseases arising from apparently the same causes; and had he considered sufficiently that during the warmer summers and colder winters of European continental countries than of England, the usual difference between the temperatures of the external atmosphere and of the air within doors is much greater than in England, with corresponding difference of specific gravities, and therefore that the ventilation of buildings there going on through apertures of the same magnitude, is much more complete than in England.

It was with such facts before us as are related in the preceding paragraphs that, in a Report on the fevers of London, made to the Poor Law Commissioners in 1838 by Dr. Kay, Dr. S. Smith, and myself, we recommended as the great preventive and remedy the adoption of measures to maintain purity of air in and about the dwellings of the poorer classes, who, from other causes connected with their poverty, are particularly liable to have the disease. The wisest government may often have difficulty in maintaining such a state of the political body that the labouring classes shall all have abundance of good food, clothing, and other necessaries of life; but any government, by simple legislative enactments, may determine that streets and houses everywhere shall be so constructed as to be well drained and ventilated, and that there shall be a proper service of scavengers, &c., thus preventing any hurtful original generation of malaria, and if contagious disease by any means be induced, so diluting the poison by plenty of pure air as to extinguish the epidemic.

Dr. Alison, the distinguished professor of medicine in Edinburgh, thought that, in the Reports referred to, too much importance had been attached to malaria, and too little to other particulars noted in the above table, and usually classed under the general head of "destitution," and which are here represented, in relation to fever, as only predisposing causes. The answer to this animadversion is given in my observations on the Report which contained it, and which, with my observations, will probably be published with this paper. In those observations I have touched upon the subject of contagion with the view of showing, that, to hold contagion to be the sole cause of any disease, is in effect to assert, either that the first person who had the disease got it from somebody who had it before him, or that the disease was created in him as a separate and distinct existence; neither of which opinions has ever been deliberately maintained: and I did it with the further view of remarking that a great impediment to the spread of correct notions on the subject of the origin of diseases, has been the opinion, very general among professional men, that diseases might proceed from contagion alone, or else from certain combinations of such circumstances as cold, hunger, fatigue, &c., occurring in the ordinary course of nature, but that the same disease could not proceed indifferently from both the one source and from the other. Yet no truth in medicine is now better ascertained than that diseases proceeding from the influence of an accidental combination of ordinary circumstances do become contagious, that is, do spread from one person labouring under the disease to another person at the time in health.

To show in what ways the analysis of the subject of the welfare of communities has been attempted by some able and zealous men, I may mention that at the meeting of the British Association for the Advancement of Science, held at Glasgow in September, 1840, the following four views were given as to the cause and chief remedy of the misery and diseases prevailing among the poor of Scotland, not one of which made particular account of the malaria of filth, to which the London reporters had attached so much weight:—

1st. The benevolent and eloquent Dr. Chalmers held that the want of good religious training was the cause, and that church extension was the remedy.

2nd. The enlightened Dr. Alison held that destitution was the cause, and a good poor law for Scotland the remedy.

3rd. Another good man stated that the abuse of intoxicating drinks was the cause, and a legislative or other suppression of this the remedy.

4. And, finally, another gave his reasons for believing that want of national education was the cause, and the establishment of such schools as he described the remedy.

Now, to a person not scrutinizing those statements closely, it might appear that great differences of opinion on this very important subject existed among those who had the most considered it, and that little trust, therefore, was yet to be placed in professional or other opinions upon it; but, on a closer examination, the apparent differences vanish.

1st. By religious training and church extension, Dr. Chalmers evidently meant something which should make the whole people temperate, industrious, orderly, and cleanly—prosperous therefore, in a great degree, and possessed of sufficiency of the goods of life. That such a reform, if effected, would cause nearly all diseases to disappear, there can be no doubt: and so far is the scheme from being at variance with that of those who prepared the Report on London, and who advise the maintenance of purity of air in dwellings as the chief immediate means necessary for the prevention of fevers, that, in addition to giving the good which they aimed at, it seeks to give all the other goods which should change this earth, often called a vale of tears, into a paradise or heaven. The pity is, that the many good men who have before hoped to see such results accomplished by such means have met with difficulties not foreseen by them, and which they could not surmount—difficulties which have not yet disappeared.

2nd. The advocate of national education anticipated from the adoption of his scheme most of the advantages hoped for by Dr. Chalmers, and judged it less likely than that of Dr. Chalmers to be opposed by sectarian feelings; and he knew that in the degrees in which it has already been obtained, it has effected prodigious good. Then a good education could not fail to teach the effects of filthy dwellings and the means of avoiding them by cleanliness.

3rd. The opponent of intoxicating drink had to show, not only the direct injury done to the health both of mind and body by intoxication, but that by inflaming vicious propensities, and suspending and weakening the understanding, it often left the victim as if he had received neither religious training nor secular education. And so far was he from being opposed on great points to Dr. Chalmers and the proposer of national education, that he thought that one of the chief uses of the money saved by persons becoming temperate would be to secure the useful cultivation of the mind.

4th. Lastly, Dr. Alison, in urging the relief or prevention of extreme destitution by a good poor law for Scotland, sought the many undoubted and great advantages obtained elsewhere by the existence of such a law; among which are the removal of obstacles to the spread of religion, temperance, and education, and security to a certain extent against the filth which is sure to accumulate where extreme want and despair make people regardless of causes of diseases generally. But that a good poor law will not prevent fever is proved by the sickness occasionally seen in various towns in England where such law has long existed.

It follows, therefore, that the four apparently different proposals have so nearly the same objects in view—that the advocate of each values the object specially named by him in a great degree because it is supposed to bring the other three along with it. And although no one of the proposals furnished a precise answer to the questions given to the London reporters, "What is the immediate or proximate cause of spreading fever;

and can that cause be removed?" they do in no sense contradict the answer given by the London reporters—that impurity affecting the air is the great cause, and the prevention, diminution, or copious dilution of that impurity, the great remedy for the evil; and they suggest no obstacle to the doing at once by public enactment that which is important and comparatively easy, because other important objects cannot be obtained at the same time.

[*The Report then speaks of the impure quarters of Edinburgh and Glasgow, and the occurrences in them—all supporting the views above given.*]

SKETCH OF A PLAN FOR WARMING AND VENTILATING THE YORK COUNTY HOSPITAL.

(*Given to the Rev. W. V. Harcourt*, 23*rd June*, 1849.)

In any building containing separate rooms there cannot be perfect ventilation for all the inmates, and at all times, if the system be defective in respect to any one of the following six means:—

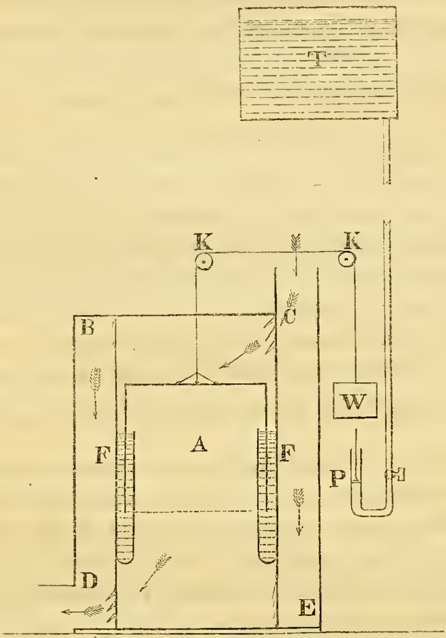
1. Of moving uniformly through the building the known quantity of air required.
2. Duly distributing this to the different rooms.
3. Properly diffusing the air in each room.
4. Causing the vitiated air to depart from near the ceilings, where it tends to accumulate.
5. Sufficiently warming the admitted air.
6. Giving to the air sufficient moisture.

The Hospital is to contain 100 patients; 20 cubic feet of air per minute to be supplied to each patient; 2,000 cubic feet per minute for the whole.

1. The air-moving is to be effected by an air-pump. A suspended cylinder A, balanced over pulleys K K, by the counterpoise W, with the mouth dipping into water at F F, like a common gas-holder, the cylinder being enclosed above at B C F F,

so that whether rising or falling, it expels equally its bulk of air through curtain valves, near D when falling, near B when rising into the eduction air-channel B F D. The air

Fig. 22.



enters the pump simultaneously by corresponding admission valves near C and E, out of the channel C F E, by which the pure air approaches the pump. A cylinder containing 500 cubic feet, making two double strokes in the minute, would supply the required quantity; or one of smaller dimensions, with quicker motion. The choice to be determined by circumstances.

The moving power to be the force of water descending from a cistern T, near the roof, which cistern will be filled daily by the water-company of the town. The water will act on the piston of a small water-engine or pump P, of which the valve will be opened and shut by the weight W at the top and bottom of the stroke.

The air to be measured by the number of strokes of the pump allowed in the minute, depending on the adjusting cock in the tube leading from the cistern.

2. *Distribution* of the air to be by a branching channel from the pump to the different rooms. Regulating valves or meters are to be placed at convenient parts of the ramification to determine the quantity of air admitted to each subdivision.

3. *Diffusion* to be secured by letting the fresh air issue from covered chinks all along the skirting-boards of the wards or in the floors.

4. *Escape of foul air* to be by openings near the ceilings, communicating with the chimney-flues, or with a general foul-air shaft, and having valves to prevent any return.

5. *Warming* of the fresh air to be effected by two self-regulating water-stoves, capable of keeping 800 square feet of water-heated surface, at a temperature of about 200°. The entering air will pass in contact with the heating surfaces.

6. When additional *moisture* is required a regulated jet of steam from a convenient boiler will be diffused in the entering air-passage.

All open fires in the building to be supplied with fresh air by direct communications from the outside, at each of which there must be a regulating valve. And every fire-place to have the space over the fire contracted, and a damper placed in the chimney-throat to prevent the waste of fuel, and of the warmed air of the room escaping by the chimney. And into every chimney-flue, near the ceiling, there will be a balanced ventilating valve. Much warmth will be saved in winter, and the temperature will be rendered more uniform, if in the wards the panes of the windows be made double.*

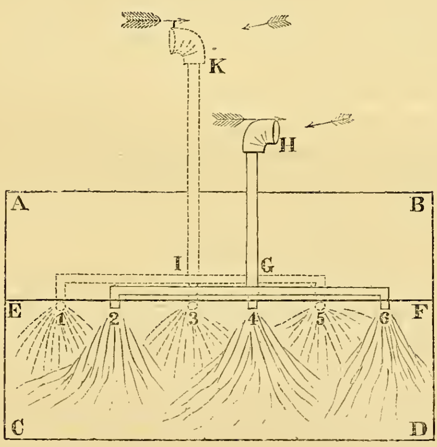
* This plan, as ultimately carried out, is described at page 170. By substituting the smokeless grate, which had not at that time been constructed, for the ordinary grate, the arrangement will be rendered still more complete.

PLAN OF THE DORMITORY AT FIELD-LANE RAGGED SCHOOL.

(Referred to at p. 190.)

A rough building, which had formerly served as an iron foundry, about 60 feet long, A B (Fig. 23), 30 feet high, C A, and 40 feet broad, was divided by its one floor, E F, into an upper room, A F, about 12 feet high, used as a school-room, and a lower portion, 18 feet high, which afterwards became the dormitory. The Earl of Shaftesbury, having learned that many houseless individuals sought shelter during the winter nights in the unclosed cellars of an unfinished new street in the neigh-

Fig. 23.



bourhood of the school, charitably planned to have the floor of the vacant space under the school-room covered with sleeping benches to receive them. It was soon found that when the crowd increased, the atmosphere, loaded with their breath, and the foul emanations from their bodies and clothing, became so offensive, that windows or doors had to be set open, and in consequence catarrhs, rheumatisms, &c., began to prevail. Lord Shaftesbury consulted the writer as to cheap means of ventilation; and the following plan was given:—

By the sides of the six beams, which appear under the ceiling supporting the floor of the school above, let tubes of about a foot square be formed of plank. These will be open by chinks all along their edges, and by holes in their sides and under surface, to allow air to pass. Of these tubes one-half, viz., numbers 1, 3, and 5, will allow the ascending hot foul breath and exhalations to pass away (as indicated here by dotted lines), towards the chimney I K, with which they are connected; while the other half, numbered 2, 4, 6, will admit fresh air all over the place, to subside gently and spread among the sleepers, as indicated here by the short lines. The three fresh-air tubes may have their ends open to the atmosphere, through the walls, except that a wire-gauze will be stretched across to prevent the entrance of birds, and to support light curtains hanging within, which will yield to admit air when the wind blows, but will lie against the gauze and prevent the escape of any air which has once entered—or they may be branches from a fresh-air shaft, or channel H G, having a cowl at its top H, with the mouth always turned to the wind. If air were visible, there would be seen here, three cool descending masses under the fresh-air tubes, and three impure heated masses between the others rising to the hot-air tubes of departure, the two sets mingling at their confines, but still very distinct.

After these tubes were made and in action the condition of the room was so changed, that more than a hundred persons slept there every night without unpleasant odour being perceivable, even by strangers entering to examine it at advanced hours of the night,—which many did, to test the truth of what they had heard as to the favourable result of the experiment.

It was observed at first, as no cowls were used, that the ventilation did not begin immediately on the entrance of the crowd, for at the end of half an hour there was a degree of smell and closeness, which, however, then quickly passed away. The explanation is, that the free discharge of the foul air was not effected until the shaft I K became warm, and that did not happen until the crowd had breathed there for a certain time. The writer hearing of this, desired that the gas-lamp should be placed so as to discharge its burned air into the ascending shaft, and afterwards the ventilation always began immediately.

WARMING AND VENTILATION IN THE ROYAL HOSPITAL, AT CHELSEA.

(Referred to at p. 190.)

Chelsea Hospital for old and invalid soldiers, has been noted like similar establishments on the continent, for the offensive condition of the atmosphere in the wards. The authorities determined lately to have the faults corrected, and several respectable tradesmen, accustomed to such undertakings, were requested to furnish plans and estimates. The cheapest of these was to cost about 2000*l*., the highest about 5000*l*. The competitors all contemplated effecting the ventilation by spacious heated shafts of brick. Such shafts happened to have been originally formed there with other views, and therefore to build new ones formed no part of the estimated expense. The opinion of the writer was requested, and he stated his conviction that the shaft-ventilation would prove as unsatisfactory there, for reasons of which some are stated at page 174, as in many other cases where it had been tried; but that a changed condition of the existing fire-places would secure with certainty in all seasons the ends desired, and at the cost of a small fraction of the lowest of the general estimates. He referred to a modification of the smokeless fire-grate, with adjuncts, described in Part First of the present work. The authorities determined to see the effect first of a partial change of one of the existing grates, and the following changes were made:—

1. The vacant space over the fire was contracted, as described at page 12. 2. A regulating valve was placed in the chimney-throat, as described at p. 13. 3. A ventilating valve was placed in an opening made through the wall into the chimney-flue, as described at p. 16. 4. A branched tube was formed

leading from every bed or cabin of the ward to the ventilating-valve, and also from the water-closet, p. 18. 5. Fresh air was admitted by a channel leading directly from the external atmosphere to an opening under the fender, p. 15.

These changes caused, 1. Much more heat to be retained in the ward from the combustion of a given quantity of coal. 2. The chimney-draught to be many times stronger than before, so as to cause a strong in-flow of vitiated air at all the openings of the branched tube leading to the chimney-valve. 3. All foul smell was removed—a fact particularly noticed in regard to the water-closet, which had been shockingly offensive. 4. The chimney never smoked. 5. The warmth was more equally diffused than before.

Other modifications have subsequently been made in the three other fire-places of the same story of the west wing of the hospital; to show how a boiler of water, or an oven, can be connected with the grate, and to show that the open coal-fire can be rendered altogether smokeless; but the author has not yet had time to examine these modifications, and to give his final recommendations. The governors will probably appoint competent judges now to inspect what has been done, and to say what farther shall be done.

ADDITIONAL REMARKS ON THE MANUFACTURE, MANAGEMENT, ETC., OF THE SELF-REGULATING STOVES AND GRATES.

A stove for an ordinary room, that it may warm the room sufficiently, and yet not be itself so heated as to affect unpleasantly the quality of the air which touches it, should have about twenty feet of external surface according to the mode of estimating explained at p. 125.

The fire-pot lined with fire-brick about two inches thick may be round or square, of about ten inches internal diameter and nine or ten inches deep.

The ash-pit must be as nearly air-tight as possible, to insure that no air shall enter to feed combustion but what passes through the regulating valve. The door must therefore have its smooth face ground to fit the edge against which it rests.

All the joinings of the stove must be rendered air-tight by cement or otherwise, and the horizontal joinings, as those of the doors through which the fuel is introduced, have around them grooves of about an inch deep filled with sand, into which the flange or lip of the door dips.

The fuel for this stove should be non-bituminous, like the stone-coal or anthracite of Wales, or coke, because common coal gives out smoke which soon obstructs the chimney with soot, and in the common form no air enters but that which passes through the bars and the ignited mass resting on them, and therefore, unless the pieces of coal and consequently the open spaces between them be large, little free oxygen can reach the upper part of the fire to burn smoke or other combustible gas. In deep fires, the inflammable gas called carbonic oxide is formed, and in the large stoves of this kind which have been made, of which one or two suffice to warm a church or hospital, there is provision by means of a pierced tube surrounding the coal-box (shewn near W, W, in Fig. 12, page 149), for admitting the required quantity of fresh air above the fire to burn with all inflammable gas found there. That admission is commanded by a self-regulating valve.

The chimney must be closed below completely that no air may enter but through the stove.

The smokeless grates and self-regulating stoves which the author has used in his own house have been made chiefly by the Messrs. Bailey of 272 Holborn. The same parties have made, to his satisfaction, the water-stoves and water-leaves for hot-water circulation, and ventilating pumps like that of the hospital at York, and ventilating chimney-valves. Mr. Edwards of 42 Poland Street, also, has made good self-regulating dry stoves and chimney-ventilating valves. Mr. Slater, of 23 Denmark Street, Soho, makes correctly, for the trade and the public generally, the self-regulating stove-valve at a low price. The writer has heard also of other manufacturers who have made some of these things well; and he hopes, as he has reserved no patent right for his devices, that he will soon have to give a list of skilful workmen in whom the public may confide. He is convinced that nearly all the existing grates may be rendered smokeless grates with the conjoined advantages of small cost; and he will deem it a duty to publish the names of the manufacturers who most efficiently aid in performing towards the public the service which is here contemplated.

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