SECTION III.

METEOROLOGY, GEOLOGY, AND GEOGRAPHY.

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THE President of the Section, G. J. SYMONS, F.R.S. delivered the following Address:—

THE title of the Section of Sanitary work to which we have to devote ourselves to-day, is one which naturally suggests an idea which I would not for a moment attribute to any one present, but which is, I believe, sufficiently general to be worthy of destruction.

The idea which needs demolition may be designated the worship of the practical. I have little doubt that the perusal of the programme of this Congress has led to some such remark as the following:—"Well, the first day devoted to Sanitary Science and Preventive Medicine, and the second to Engineering and Sanitary Construction will, no doubt, be very good; but what is the use of making three days of it, and having a lot of dry scientific papers of no use to anybody, and incomprehensible by any but dreadfully scientific people?"

This remark contains two errors—(1), The assumption that there is any difference or distinction between science and practice, except, perhaps, that science may be regarded as the teacher, and practice as the pupil; and (2), the assumption that scientific papers are beyond the ken of ordinary mortals

As I have already said, I do not attribute this idea in its crude form to anyone here present; but I think that you will agree with me, that it is in one form or another sufficiently prevalent to render it worth while to show that it is not merely wrong, but exactly the opposite of the truth.

I, therefore, purpose taking the branches of science mentioned on our programme, and pointing out some of the points of contact between these branches of science and Sanitary practice.

METEOROLOGY.

Let us take, first, temperature. Meteorologists can tell us the range of temperature to which we are liable in this country; but who will point to even one house so constructed as to resist equally well, extremes of heat and of cold? As regards the majority of houses, built solely in order to be sold, it is patent to everyone that this consideration is entirely neglected. The walls are so thin that they allow the internal temperature in summer to run up to eighty degrees or more, and in winter down far below freezing. There is rarely any outlet for the foul and heated air when it has found its way up the staircases; landlords never think of providing outside Venetian blinds, and the rooms which face the sun become veritable heat-traps. Everybody knows that foul and heated air ascends, and yet (owing to the rare adoption of French windows) nineteen-twentieths of all the rooms in England have no outlet within eighteen inches or two feet of the ceiling, where, consequently, there is a permanent stratum of foul and heated air; and, as if with a desire to aggravate this evil, a quantity of gas is burned in the rooms, and the deoxygenized air rises into this stratum, and remains there. Perhaps, if it were possible to compel every builder to remain for an hour with his head close to the ceiling of the rooms he built, an alteration would not be long deferred; unless, indeed, the foul air killed them all. Everybody knows all this, but few indeed are the cases in which any attempt is made to remedy the evil.

In cold seasons it is equally discreditable to hear on all sides complaints of the inconveniences arising from frozen water-pipes, and from their leakage when a thaw follows. If the temperature in England ran down to twenty or thirty degrees below zero, there would be some excuse for such occurrences, but our winters are never so severe.

This reminds me of another case in which a little meteorology would have saved several hundred pounds and much inconvenience. An engineer laid out the waterworks of an inland English town, and either from economy or want of experience, he put his mains only one foot below the ground. He made no inquiries as to the temperature of the soil at that depth. A great frost came: the temperature at one foot went below thirty-two degrees, and so large a proportion of his pipes was burst that it was virtually a case of new mains throughout the town.

Another winter accompaniment which has occurred for hundreds of years is always a source of great confusion—I mean a heavy fall of snow. No one seems to know what is to be done, and the last idea is in many respects the worst. The tramway companies introduced the plan of scattering salt in order to dissolve the snow, and the owners of private houses have imitated them by scattering salt on the pathways in front of their houses. The result is, that the pavements are covered with rotten slush of an excessively low temperature, so cold as to lame dogs temporarily when passing over it, as to be injurious even to the well-shod, and almost unbearable to the shoeless wanderer. It would be very little trouble to sweep this soft slush into the gutters, and I think that any one using salt and not removing the resultant slush, should be not only *liable to* a small fine, but should infallibly *be fined.*

There is one subject upon which I am desirous of speaking somewhat strongly, but which is not exactly meteorological. It is, however, only a development of the remark which I have already made as to the absence of ventilation in the upper part of rooms. I will, therefore, mention it here. It is the terrible unhealthiness of our churches, theatres, and other places of public assembly. I am no chemist, or I would put before you the results of the analysis of the air in many public gatherings; but no figures are needed to prove what everybody knows. As regards churches, it is not for me to apportion the blame between ecclesiastical architects and churchwardens; but I cannot understand a preacher looking at the gradual drowsiness spreading over his congregation, and not reflecting that it is quite as much the natural result of poisoning by bad air, as of any lack of interest in his ministrations. I should not be at all surprised to learn that the opening of a few ventilators in the roofs of some of our churches was found to produce, not only more attention on the part of the congregation, but an increase in the amount of the collections; for keen interest in matters ecclesiastical is more probable when the mind and body are bright and vigorous, than when foul air has rendered the mind drowsy and made the head ache.

I am not prepared to say that all theatres are badly ventilated, and I have not much experience of the galleries, but I went once into the top gallery of a building which we were told was to combine the good qualities of all such like edifices—I mean the New Opera House at Paris, and the heat and foulness of the compound which the audience had to breathe were such that I cannot understand any one going there a second time.

At more than one place of amusement a very rough-and-ready but effective cure for this evil has been adopted by constructing the roof upon a framework which can be rolled off so as to leave the audience roofless for a few minutes. I doubt, however, whether our medical friends would not consider such a remedy worse than the disease. I do not myself presume to advocate any mode of ventilation, but may perhaps be allowed to suggest the question, whether it is advisable to trust (as is at present generally done) wholly to the current generated by the difference in the specific gravity of fresh and effete air. There are two reasons for distrusting this mode of ensuring ventilation—first, in order to secure its greatest efficiency, the path of the inflowing air must be as free from friction as possible, and freedom from friction is too often co-existent with draughts; secondly, ventilation, depending on differences of temperature, or more strictly upon differences of specific gravity, is evidently least efficient in hot weather—the very time when the general public are most clamorous for an extra supply of pure air.

The head of a Glasgow engineering firm described to me an extremely simple arrangement whereby each successive two minutes 2000 cubic feet of air were extracted from close to the ceiling of an Edinburgh hall, noiselessly, and without either heat or ice. I do not at all suggest what ought to be done, but I hold that the foul state of the air in nearly all our public buildings is discreditable to the age in which we live.

A day or two after writing this part of my address a letter appeared in the *Times*, which was so extremely germane to my own remarks that I should like to read it to you.

THE VENTILATION OF THEATRES.

To the Editor of the Times.

Sir,—Now that we are upon the eve of another theatrical season, will you allow me to draw attention to a matter which has been broached in the *Times* not many months ago—I mean the ventilation of our London theatres. During the visit of the Comédie

Française, "A Physician" wrote to complain of the ventilation of the Gaiety Theatre, whereupon Mr. Hollingshead endeavoured to show that his theatre was fitted with abundant means for the exit of foul air. I attended two performances of the French players immediately after this, and suffered much from the atmosphere of the theatre; on the second occasion to such a degree, that I was obliged to leave after the first three acts of the play, which was *Ruy Blas*, thus missing the best part of the piece. But I do not wish to draw up an indictment against one theatre in particular, but against our London theatres generally, for I have experienced the same thing in most of them, even in such well-managed houses as the Lyceum and the Vaudeville. When I attended the inaugural performances of the Shakespeare Theatre at Stratford-on-Avon, last April, the contrast was very great, and there I found that sitting through one of Shakespeare's plays was attended with little more fatigue than sitting in one's drawing-room, simply because there were a number of excellent ventilators in the roof. I rejoice to see that Miss Litton has been attending to this matter in her theatre, and I feel sure that if you can find room for this letter it will induce other managers to put an end to an evil which is so injurious in its effects to the large and increasing body of theatre-goers.

I am, Sir, yours, &c.,

September 19. A Regular Playgoer.

Excuse this digression, and allow me to return to the more direct relations of meteorology with Sanitary matters. People of the *cui bono* class are, I believe, yearly becoming more rare, but there are thousands still who would doubt what possible use it could be to know how many miles of wind blew over Greenwich yesterday; and a still larger number would fail to see what possible bearing such a fact could have upon Sanitary matters. Mr. Haviland would tell us that both the direction and strength of the wind ought to be considered in laying out the plan of a town or of large additions to existing ones, and in the past, if not in the present, great care was taken that country residences were protected from objectionable winds by belts of trees. There is, however, a still closer connection, for the members will not have forgotten that this Institute is, and has been for a long time, conducting a series of experiments upon the effectiveness of several patterns of cowls, and that these experiments have been conducted with anemometers and air meters at the Meteorological Observatory at Kew.

Moreover, questions of ventilation, both for public buildings and especially for hospitals, are almost wholly determined by means of small air meters, which are merely delicate anemometers.

Lastly, it is a rather curious fact that upon the summit of that modern Tower of Babel, the Queen Anne Mansions, Mr. Hankey has put an anemometer. I wish he would put another in the court-yard, and publish the records of both. Joking apart, I hold that if premises are to be carried to that height, the streets must be proportionately wider; for the air in a street of ordinary width, but with buildings of that height on each side, would scarcely ever be changed; its only purification would be by the passage of such portion of the rainfall as escaped falling against the houses. The notion of walking through a future London composed of streets of their present width, and houses as high as Mr. Hankey's, is the reverse of agreeable.

Take, again, ozone. I am not going into the chemical question, nor the strictly meteorological one; but in spite of all the demonstrations of the inutility and inaccuracy of the old-fashioned ozone test-papers, I think that they were giving us more useful information than we seem likely to obtain from the more scientific methods which have been declared to be alone of any use. We want some rough-and-ready test of the purity and healthiness of the air in different localities, but at present I know of none. The old-fashioned ozone test-papers had, doubtless, a multitude of faults—I have attacked them somewhat vigorously myself, and Dr. Cornelius Fox still more so; but unfortunately the arrangement which he proposed to substitute was so elaborate, that at the present moment I do not know of a single place in the whole of the British Isles where it is at work. Faith in the old plan has been shattered, and the new one has not been adopted. Perhaps it may be well to epitomize the old method and its faults, as it may lead some one to suggest a safe and simple course. And first, as to the method. Sheets of absorbent paper were dipped in a solution of iodide of potassium and starch, dried, cut into small strips, made into bundles, and sold in boxes. Observers were instructed to take one out each morning, hang it up in a place open to the air but shaded from light and of course from rain, and on the following morning to note the amount of discolouration by comparing it with a series of ten pattern-tints supplied with each box of papers; if there was no discolouration the entry was 0, if the paper was rendered quite a dark brown the entry was 10, and intermediate numbers for intermediate discolourations.

So much for the method; now for the faults. The discolouration

is effected by the contact of air with the paper; therefore, if on two days the amount of ozone in the air is the same, but the wind blows twice as strongly on one day as on the other day, it is obvious that the discolouration will also be double. This difficulty can be overcome in two ways—(1), by applying to the observed discolouration a correction corresponding with the total horizontal motion of the wind, as recorded by an anemometer placed near the end paper; or (2), by sheltering the test-paper from the wind and drawing a measured volume of air over the paper by an aspirator. The papers after exposure and colouration may, by the action of antozone or damp, be bleached before the usual hour of observation, and whereas 7 may have been reached some hours previously, at the regular observation hour the paper may only show 0 or 1. The late Dr. Lankester proposed to get over this difficulty, and also to determine the variation in the amount of ozone during the twenty-four hours, by using the paper in long strips, and winding it by clockwork from one drum to another under a small aperture. I do not think that he arranged his machinery with an intermittent motion, so that each portion should be exposed for some definite period—say, an hour, and then suddenly replaced by another portion, and so on, but that would obviously be the proper course.

There are many other imperfections charged against the old plan; but I will mention only two others. The papers were said not to be equally sensitive, and therefore the recorded discolourations were not strictly comparable. I believe that this ground of complaint arose chiefly from the very limited demand for the papers, and from the fact that there was so much jealousy among the opticians that, instead of all buying from one source, each tried to make his own. I have left the most serious charge to the last. Chemists of high position said that there was no certainty that the discolouration was in the least degree due to ozone, and, I believe, proved their case by tinting the papers by half-a-dozen processes when no ozone was present. Perhaps, however, we shall find that the papers give us useful information, even if they tell us nothing about ozone.

In this as well as other countries, the public attention given to scientific work is not proportional solely to the merit of the work, but is dependent on two factors: A, the social and scientific status of the worker; and B, the merit of the work. Meetings like the present tend greatly to diminish the value of the factor A, and I sincerely hope that before long it will vanish entirely, and leave the factor B the merit of the work, as its sole credential. You may wonder at the insertion of this digression; but it was induced by my having resolved on now mentioning, for the first time, a few experiments which I made nearly five-and-twenty years ago.

I arranged with friends residing in various parts of the metropolis—one in the City, one at Whitehall, others at Chelsea, Notting Hill, Blackheath, Camden Town, and Camberwell—for three months' continuous observations of the amount of ozone. We took all the steps that we could to secure uniformity, even taking the precaution of cutting each ozone slip into portions so that all the stations used the same slip on the same day. At the end of the month the portions were returned to me and mounted as one slip for each day. That they in the least indicated the amount of ozone, I am not going to assert; but this I can safely say, that no matter from what direction the wind blew, the papers in that quadrant of the metropolis first reached by the wind were always more darkly tinted than those in the centre or in the opposite quadrant: those at the central stations were scarcely ever tinted. Similar results were, I believe, obtained by Mr. Glaisher during the cholera epidemic in 1854, and, though no special arrangements were made to ensure identity of paper, I do not think that the accuracy of the results was thereby vitiated. These very simple and inexpensive tests may be beneath the contempt of the optimists of ozone observers, but they at least prove that there is some quality in air coming from the country to the metropolis which is extracted, not only before passing over the whole of London, but even before passing over half of it, otherwise the central stations must sometimes have recorded traces of discolouration.

That there is a wide difference in the healthiness of different localities is indisputable, and that there is more in it than is revealed by either barometers, thermometers, hygrometers, rain gauges or weathercocks, is equally certain. Something may be learned by the chemical analysis of large volumes of air; something, indeed a good deal, is being learned at Paris by drawing a stream of air over glycerine and examining microscopically the particles of dust deposited. But we want something more handy. It is too bad that there should be no easy means of determining the relative life-supporting properties of the air in Hyde Park and Seven Dials. I do not for a moment say that the old-fashioned ozone papers will do it, but they are the nearest approach which has yet been made, and I should be very glad if they can be supplanted by something better.

Mists and Miasma.—Before proceeding to consider mists in their relation to public health, I take one moment to say that if any of my hearers have ever seen in this country the presiding genius of mists—I mean the *ignis fatuus*, or "Will o' the Wisp," I shall be greatly obliged by their favouring me with full particulars. I only make this request because, in the course of long search, I have not met with one person who has seen it; and I am sure that, especially after the present soaking season, drainage operations will proceed so rapidly that future opportunities will be rare indeed.

Here, however, we are concerned with mists and their influence upon health. You doubtless remember the remark of the country doctor, who, walking up a hill, passed from the valley mist into the clear air on the hill-side, and turning to his companion, remarked that that white sheet covered all his best patients. I wish we had statistics of the mortality in some of our old monasteries—Fountains, Tintern or Rievaulx—for the localities are equally noticeable for their beauty and their mists; and although the regularity of the monastic life might conduce to longevity, I should have thought such damp localities very ill-adapted for such residents. It is often suggested that our ancestors were stronger than we are, and that, as much of their time was spent in the open air and in hunting, they were less susceptible to the Sanitary evils of their houses and castles. But the monks, even those who were not actually studious, did not lead by any means an equally active, open-air life. Were they, then, able to throw off the effects of damps and mists, or did they fall victims to them without knowing the cause? We, however, with all our nineteenth-century artificial and high-pressure life, know perfectly well that a "lovely spot embosomed in trees and encircled by hills," is usually characterized by a damp, misty, cold, and stagnant atmosphere. We know that these conditions are not adapted for vigorous health; and yet how many persons will rush blindfold into the arms of the doctor, simply for the sake of a pretty view! Persons generally select residences, and the sites for new ones, when the weather is fine and the sun shining. There is no reason for their discontinuing the practice; but many selections would, I think, be abandoned if an hour or two of the twilight and night were spent in examining the distribution of the mists in the locality. When we remember that few persons spend less than half their time indoors, it is surely not asking very much to urge that an hour or two should be devoted to examining roughly the conditions of the air which will in future surround them for half their lives.

You may think that I attach undue importance to mists, and

I will, therefore, give you a short chapter of personal history. A relative had a great desire to spend his autumn holiday in a beautiful, hilly, and well-wooded part of the south of England. Unable to obtain quarters on the high ground, he was induced to take a very clean little cottage on low ground; not, however, very near the river which ran through the little town. At first, four of the family went down, and three of them were speedily attacked with diarrhœa; another relative followed, and was similarly attacked; and finally I arrived myself. I was told of the state of affairs, and advised not to touch the water—on which all the blame was laid. The last train had left; and, moreover, I felt desirous of investigating the case. After dark we went out for a little stroll, and found the air excessively damp; in fact, there was a white sheet over the whole place. Next morning, I was as ill as the rest of the party. I had with me some permanganate of potash, and tested the water from two or three sources with it; but the colour remained absolutely unchanged; so I suppose there was not much the matter with the water. One of the party started off after a doctor; the doctor was out, but the assistant said directly, "Oh, no; it is not the water; strangers are almost always attacked like that; but they soon get better, or else they go away. You see," he added, "this valley is supposed to have been under sea water not long ago, and all the fields from here to the coast are terribly misty and agueish." I need hardly add that it was not many hours before the whole party migrated to a high, dry and sandy soil; but it was only by sleeping in the locality that the evil was incurred, and had we only seen the spot by daylight scarcely a suspicion of evil would have crossed anyone's mind.

Closely connected with the existence of mists is the amount of evaporation,—a subject upon which we are in nearly the same unsatisfactory condition as I have explained to exist respecting ozone. Some very elaborate, rather costly, and I believe extremely important observations upon this subject, were commenced more than ten years since, and have been conducted under the supervision of Mr. Rogers Field. We are still waiting for his full report on the subject, but it is understood that all the old forms of evaporator are useless, and no new pattern has been introduced in their place. The only two points of contact between evaporation data and Sanitary work which occur to me are—(1), that evaporation data would be serviceable in computing the yield of storage reservoirs, a point upon which I believe no information is published, and not much exists; (2), data as to the amount of evaporation would be very useful in connection with sewage irrigation, for it ought evidently to be most successful where the air absorbs the largest amount of surplus moisture.

Hygrometry is almost identical with the measurement of evaporation, but not quite; because hygrometry considers the amount of moisture in the air at rest, and evaporation is the resultant of the passage of a variable number of miles of air of a variable hygrometric condition over a water surface. I am afraid this point is hardly clear: I will therefore put it in another form. The air we breathe is, you know, a compound; there is first an approximately constant quantity of oxygen, hydrogen, &c., and secondly a very variable quantity of water in the invisible state of vapour. It is the business of hygrometers to tell us how much water there is in the air. It is never very great, fifteen grains of water in a cubic foot of air is the extreme, perhaps a trifle beyond the extreme, which ever occurs in this country, while it may run down to one grain per cubic foot. The hotter the air is, the more water can it contain, and hence the high temperature always given to drying-rooms; and hence it follows that though a room may be dry while it is kept at a high temperature, it will very likely become damp when the temperature falls. A striking illustration of this is reported to have occurred at a ball in Russia. The night was cloudless and very cold, but the room in which the ball was being held was, as is usual in that country, close and hot. A lady fainted; and as fresh air could not easily be obtained, the windows being frozen fast, an officer broke the glass with his sword. The clear cold air rushed into the room and cooled that inside so rapidly, that the vapour became mist, the mist became frozen, and snow was formed in the room.

Some people err the other way, and especially in cases of illness; distress the invalids, and check their recovery by allowing the air to become too dry. I suppose matters may change in the next generation, but at present either a doctor or a nurse would be considered a pedant, who used a hygrometer in order to regulate the air breathed by a patient. I am glad to see that we are progressing in that respect. Two generations back the subject of the hygrometry of the sick-room was unknown. Twenty years ago, a paper spout on the nozzle of a tea-kettle was the most advanced apparatus, and now we have got as far as regular vaporizers; but I have not heard of any general demand for hygrometers to indicate when, and to what extent, vaporizers are to be used, and I fear that much is still left to the personal sensations of the medical attendant and the nurse, although it is just as easy to order what shall be the hygrometric state of the sick room, as what shall be its temperature, and I think it probable that in many affections of the respiratory organs the former is of more consequence than the latter.

There is another matter in which hygrometry ought to come home to many, especially at a period when people seem so prone to forsake old and comfortable houses for new and showy ones. Almost before a house is finished, and long before the water necessarily used in its construction has had time to dry out, people rush in to reside, and then there are rumours of colds, rheumatics, &c., as if anything else could be expected in such a climate as that of the British Isles. I am not going to show how the hygrometer would enable people to adopt this course with impunity, but there are many ways in which it would teach them what to do, and what not to do. By-the-bye, there is a paragraph in Sir Edmund Beckett's treatise on "Clocks," which bears closely on the question of drying-rooms. He says—"The clock-room at the Exchange was at first made with the object of keeping out the dust and damp in every possible way: even the slits in the floor for the ropes had sliders to them; the clock was enclosed in a glass case, the plate glass cover originally placed over the escapement being found not enough to keep it from the damp. When the clock was repaired, and some of the brass-work replaced with iron in 1854, I suggested the removal of all this glass, and encouraging instead of preventing a draught through the room. This was done; and although the wet used to stand in drops upon the clock before in damp weather, it has been perfectly dry ever since. The same thing has been found in small clock-cases; they may easily be too air-tight. I do not mean that there is any objection to enclosing a clock in a case, and of course it is absolutely necessary when the clock-room cannot be kept locked against everybody but the man who has the care of it: only there should be a draught through the room, and the case itself not too close to let air through it."

Lastly, I come to the rain—and here the points of contact with everyday life and with Sanitary matters are so numerous that it is hard to know where to begin and harder still to know when to stop. Fortunately for us all, I need say very little to-day on the relation between rainfall and national water supply, because I stated fully my views upon that subject in my address upon Water Economy at your anniversary meeting; and it is for others either to refute my statements or to carry out the course suggested. Unfortunately there is another course, which is so easy that it is

generally preferred—I mean the ruinously costly one of *laissez faire*. The question of national water supply in its broad features is epitomized on page 21 of the address just mentioned, and the longer the time before action is taken, the greater will be both the confusion and the cost.

I leave the question of national water economy where I left it before: ripe for the action of our legislators.

The amount of rain is, I need hardly say, a most important element in all sewage questions; I say *all* advisedly, because even where attempts are made to exclude rain water from the sewers, no one claims to have succeeded perfectly, and even if he did, the rain question would very likely come in again as affecting the administration of a sewage farm.

By-the-bye, I trust that Mr. Rogers Field will try to apply his recent researches upon syphons to the flushing of drains by cumulative discharges of rain water.

The remarkable absence of some classes of disease during the period in 1879 when summer was expected to occur, may have been partly due to low temperature, partly to the absence of the usual supply of unwholesome fruit; but I think part must also be ascribed to the scouring of the streets and drains by the superabundant rains. And there is something else washed by the rain, greatly to the Sanitary advantage of residents in towns—I mean the air. Those who have leisure and inclination can follow this subject up by perusing Dr. Angus Smith's book on "Air and Rain." I will merely call attention to one proof of its important action, which is patent to everybody who uses his eyes—it is an almost invariable action, but I will take a strong though not overcoloured illustration. It is a summer evening, close and thundery, the air is thick partly with moisture but chiefly with extremely fine dust, particles of almost endless variety, fibres of cotton and of wool, soot, pollen from flowers, granite, road dirt, &c., &c. No thunder occurs, but there is a downrush of colder air: rain begins, and in an hour it is over, and has carried with it to the ground an enormous proportion of the miscellaneous compound which the inhabitants had previously been breathing. If you ask for proof of this, I merely refer you to the street-lamps; watch them regularly and you will find them nearly as good at revealing the dust motes in the air, as the beam of light from Professor Tyndall's lamp. Under the conditions I have described, they shine with a brilliancy rarely seen. Metropolitan air wants washing, it is wonderfully better for the process, and I suspect that that is one reason for the low mortality in 1879.

Rain as a supply of drinking-water will be considered in one of the papers to-day; and in two or three others we shall have rain before us in its relation to the yield of wells. On those two points, therefore, I need say nothing.

GEOLOGY AND GEOGRAPHY.

In the programme of this meeting, Section III is stated to be devoted to Meteorology and Geology; but on the Congress tickets it is said to be for the consideration of papers Meteorological, Geological, and Geographical; which seems to me much better, for really the questions which we have to consider include all three branches of Physical Science. Perhaps we might include all under the single term Physical Geography, or, as I believe the South Kensington authorities now call it, Physiography.

Physical geography is the key to the, as yet, uninvestigated question of the true merits of our various health resorts. I am glad to state that I believe very shortly the Meteorological Society will have in operation a system of absolutely identical observations at a considerable number of these health resorts, and not limited to one station—in, for example, Brighton; for who would contend that the climate was identical on the racecourse and in Old Steyne? Years ago, Dr. Wigan wrote a little book on "Brighton, and its Three Climates," and the title expresses what probably exists more or less in nearly all our health resorts—and, Why? Solely because of the variations in the physical features of the locality—Hastings, Torquay, Llandudno, Tunbridge Wells. A moment's reflection respecting any of these places will convince you that in each you may find great climatic differences, precisely in accordance with the principles of Physical Geography.

As to the bearing of Geology on Sanitary matters, I think there is only one point upon which I need offer any remarks. The theory which I desire to submit will probably strike you as being wrong, if not ridiculous; it is this, a house on a clay soil is not necessarily more unhealthy than one on gravel. One great mistake in house-building, both in town and country, is in grudging a few courses of bricks, and so letting some of the rooms be at, or close to, the level of the soil. In isolated cases floors laid flat on the earth may be tolerably dry, but in the majority of cases they are not, and in no case can such floors be desirable for persons of delicate health; and with reference to the relative merits of clay and of gravel, I would just submit two facts—(1), the clay under a well-drained house becomes so dry as to be almost dusty; and (2), although the probabilities are in favour of gravel becoming even drier than clay, yet should any offensive matter get into a bed of gravel, it would circulate more rapidly than in clay.

With reference to gravel and clay I may give one hint, based upon experience which I regret, but which may be useful to others, though it is another chapter of personal history.

Upwards of twenty years since, my father was suffering from consumption, and after two or three places had been tried, the physician and medical attendant advised that he should go to the upper part of Richmond, because it was high, it was away from the river, and on the gravel. A suitable house was found, and it was considered very satisfactory, because near to it some new houses were to be built, the foundations had been excavated, and all the removed soil was a fine gravel. The patient became rapidly worse, and after one or two consultations he was removed to Blackheath, where he speedily improved, and lived through a subsequent winter. Some time after taking the Richmond house, we found that the gravel was not only no advantage, but, as it appeared to us, the reverse, for there was a thin layer of gravel lying on a bed of clay, as was shortly proved by the foundations, which I have just mentioned, being found with several inches of stagnant water in them. All this is doubtless very obvious, but at any rate it may save others distress by warning them not to be satisfied with a merely superficial layer of gravel.

You will probably think it a strange omission on my part if I make no full reference to the relations between climate and disease, but, *Non omnia possumus omnes*. We cannot all do everything, and I can give you no newer, better, or clearer information than the world already possesses in the reports and papers of Dr. Farr, Dr. Simon, Dr. Scoresby-Jackson, Dr. Tripe, Dr. Mitchell, and Mr. Buchan; to say nothing of foreign and transatlantic investigators.

I should, however, like to say one word in behalf of the registration of disease, as distinguished from the registration of deaths. I do not believe that the general public, or even our legislators, understand clearly why experts are so desirous of obtaining a registration of disease in addition to that of deaths. To me it has always been mysterious that the records of deaths harmonize as well as they do with climatic data, for not only are half the deaths of one week registered in the following week, but a far greater source of confusion lies in the fact that though certain climatic conditions give—say, fifty people bronchitis in one day, it by no means follows that they will all die on some one other day. If the death registers were filled up with rigorous accuracy, the entries might be posted back to the dates assigned for the commencement of disease, but I doubt whether the entries are accurate enough to justify the expenditure of the necessary labour, and moreover it is at the best a very roundabout way of doing it.

Why do we not get returns of disease? I am entirely ignorant of the secrets of the medical profession—(and parenthetically I may say that I believe it would be far better if there was less mystery about matters medical. I believe it would be far better to teach our youngsters what to eat, drink, and avoid, and some of the leading features of their own marvellous bodies, than the number of the satellites of Saturn or the exact sequence of the Palæozoic rocks. Excuse this digression.)

I can think of only two reasons for the absence of systematic disease registration. (1) That medical men in small practice are afraid of allowing it to be known how small is their list of patients. This surely could be got over in many ways; the records should go direct to the office of the Minister of Health (when we get one), and there they would be as safe as income-tax returns are after they get to Somerset House. And if even this would not satisfy nervous or fidgetty practitioners, they need not sign their returns at all. Let all blank forms issued from the office bear rotation numbers, and let them be booked to the medical man to whom they are supplied; none but the two or three officials in charge of these records could possibly ascertain who sent the report. I believe the objection to be absurd, but I have shown that it can be entirely overcome. Moreover, I am not sure that the actual number of cases is needed; I think it very likely that it would be more useful to record the percentage of all new illnesses due to each class of disease. The (2) ground of objection may be supposed to come from the man with a very large practice; he may say that he has not time for filling up any more returns. I wish those who are so situated would think of their younger professional brethren, and benefit themselves by helping others: but few people in any profession or business seem to be able to say, "I have enough now; I will let some one else have a turn."

But how are we to get returns from these people? I fear the only answer is by paying for them; for though I believe that many of them love their work, and wear themselves out with their practice partly through that love, and though surely the majority of them would like to leave the world wiser and better for their having visited it; yet I fear there is no denying the fact that, unless a registration-fee sufficient to cover the cost of the dispenser's time in making up the return is offered by the Government, little progress will be made. I am sure that it would be a good investment of national money. For who will affirm that, in the future, disease signals may not be as usual as storm signals are now?

At the close of his address, the Chairman (Dr. Richardson) called upon Mr. A. Haviland to move a vote of thanks to Mr. Symons for his address; this was seconded by Dr. L. Marsh, and carried.

Dr. Richardson then spoke at some length, touching upon the principal topics raised in the address, and pointed out that hygrometric and temperature observations were taken at some hospitals. Dr. Richardson also announced that a Supplementary Section would be held on Saturday morning, the 25th October, for the reading of Dr. Balbirnie's and other papers which stood *over* from the previous Sections; and also that an Excursion to the North Surrey District Schools, at Anerley, would take place in the afternoon.—Dr. Richardson now resigned the chair to the President of the Section.

Mr. Symons thanked the meeting for their attention and for the manner in which they had received his address. With respect to the remarks of Dr. Richardson, he would confine himself to two points. Dr. Richardson had mentioned that at some of the hospitals hygrometric and other observations were taken, but the complaint which he had made was that the hygrometer was not used in ordinary private practice; and he had not yet met with an instance of that being done.

As regards the registration of disease and the alleged readiness to afford such information and desire on the part of the medical practitioners for the publication of such data, Mr. Symons felt doubtful, because the medical men of the United Kingdom were so numerous (about 18,000), and so influential that if they really wished for anything of the kind, they could bring such influence to bear upon Parliament as to obtain such a small matter without the slightest difficulty. As they did not take such steps, he feared that their interest in the subject was by no means so keen as that of the leading members of the profession.

Geology in relation to Sanitary Science.

It is a charming and recreative amusement, especially to the much-worked mind, to speculate on what in future ages may obtain among men in regard to their health, physical and mental strength and beauty, and their length of days. The vision of fair women and strong men living without disfiguring decay until twice three-score years have revolved with them in their journey through life, is like a pleasant dream; and like all pleasant dreams, gives evidence of a healthy parentage—unlike the morbid imaginings of an oppressed mind, labouring under a load of crude and indigestible ideas. This vision has the merit of so impinging upon our minds, as to make us reflect and earnestly consider, whether the scene presented to our mental vision, clothed as it is with apparent reality, if not a reality now, can ever become a possibility. There is nothing unnatural either in the figures or their proportions in this fair vision of man's future earthly life. It contains no ghostly monsters to affright, no so-called superior beings, with plumed anatomical impossibilities, to be wondered at with humiliation: no phosphorescent halos distinguish the good, no sulphur fumes betray the presence of the bad. The men, the women, and their attendant brutes, are unendowed with anatomical impossibilities. If we have learned the anatomy of the vertebrate of to-day, we shall be able to demonstrate that of the denizen of the dream, whenever that dream is realized. We presume the dreamer does not wish us to imagine that the men will be more perfect in their strong beauty than the Greek athletes, who stood as models before Pheidias, or the women more lovely than those whose lines of voluptuous beauty ravished the sculptor of the Venus de Medici. So far, then, we have nothing but what nature has already supplied, and we may reasonably expect to see the like again. Man, too, has been known to live beyond the six score and five years of the people of the dream. Man has lived, and in many instances still lives on the produce of the vegetable kingdom, without shedding the blood of his fellow-creatures. Moreover, there is nothing in his present surroundings in some few favoured parts of the world that will preclude his being as beautiful, as strong, as perfect in health and as long-lived, as he is known from the records of credible history to have been. He may still live only on the fruits of the earth. He may still live in communities governed by natural laws—his average mortality may be reduced to what is now a theoretical minimum—and under these conditions he must *multiply*. A hundred men and women starting in pairs at the time when their bodies have just completed their developmental life—which at the latest may be attained at twenty-five years—would, before each pair had arrived at the age when the reproductive powers wane, have increased to at least six-fold; and as death would neither weed out the little ones, nor excess the elders, we may expect a prodigious increase in this healthy and long-lived community.

Now it must be patent to all that, after a few generations, the vast increasing concourse must migrate either westward or eastward, northward or southward; far away from the first fertile and climatically perfect spot which first attracted their ancestors—perchance from the rich red sandstone soil, with its fertile corn-bearing and fruit-producing vales and sloping hills, well watered, well wooded, well drained, to an adjoining coal-bearing land, where the bleak and barren mountains of millstone grit rear their craggy outline above inhospitable mosses and infertile uplands—where the mineral riches beneath the barren soil await the labour of a race, whose antecedents have not taught them to endure. Forced from the paradise of their father's selection by their loyal desire to obey the most imperative of their father's laws, "Thou shalt not over-crowd thy father's house"—they bid farewell to their happy homes and cease to be what once they were. They stand face to face with the stern reality of change; a change so great they cannot realize it. At first their little ones begin to droop—the parents' hearts sicken at their new grief, and the strong stalwart man, depressed and careworn, seeks with willing hands but with misgiving heart to conquer rugged nature, and force from her the necessary food for those who follow him. The scene is changed—the dream is over—the pleasant vision, like a baseless fabric, has been swept away. Help is called for; and Science, like a good genius, extends her hand. The dreamer and the dream are gone. Large as our world may be, it never has been, and we have no grounds for believing it ever will be, a universal paradise: and without it becomes so, the people of the dream can never become realities.

The records of the rocks teach us each day how, through countless ages, our earth's crust has changed—how what once was the bottom of the sea has formed the loftiest mountains, and how again these snow-capped and ice-scored rocks have had the stable ocean rushing in strong currents hundreds of fathoms above them—and how again, like our own hills, these mountain heights have again emerged capped with tender shells and weeds, the denizens of the deep. Whilst the records of the rocks teach us this, wherever they have been searched, we find not a single writing in the stones that records evidence of either uniform climate, uniform soil, or uniform conditions of any kind whatever, conducing to the perfection of existence either among the lower or the higher classes of animals.

The very factor so necessary to the perfection of type, viz., health, is the great factor of productiveness; and this productiveness is the factor of destruction by over-crowding. Over and over again has this been recorded on the rocks. Without reason, the lower creatures are unable to modify the conditions of life; with reason, man makes the attempt and often succeeds, his first efforts being almost invariably directed towards modifying by his labour the site which he has selected for his home, either from choice or force of circumstances. He tills, he seeks for water, he selects sites for his cattle—in fact, he sets to work to obtain a knowledge of the ground on which he stands; for by degrees he has learnt how conducive to his health and happiness a practical knowledge is of the earthy crust, from which his food springs, his water is drawn, and on which his habitation rests.

Passing from the dream to the realities, which nature has engraved upon the countless strata-folios of her records, stereotyped in her huge rock volume, whose massive pages envelope the molten centre of our globe, and what do we find?

Records of change on change—records of vast floral and faunal dynasties, each of which has endured for innumerable ages longer than the oldest dynasties of Egypt or of China, and yet we have evidence that nature has allowed, in her infinite wisdom, each to be overthrown—each to become extinct—and give place to a more perfect form. Has this hitherto ceaseless revolution done its work—outspent its force? Will the first dawn of intellect, whose temple is the brain of man, blaze into perfect brilliance during the very first human dynasty on which the great centre of our solar system has ever shone? Will the sweet healthy beauty of nature's queens, the manly symmetry of her kings, so exquisite and perfect to our finite sight, ever remain, for countless ages to come, the crowning product of nature's handiwork?

Does the history of their predecessors warrant us in holding such a belief? True it is that man, unlike his humbler predecessors, has, through his inherent and novel gift of intellect, so cultured his surroundings, so educated his mind, as apparently to have improved his body form and with it the material source of that mind, which differentiates him from his companion brutes.

Apparently, I say; for is it certain that during the twice two thousand years of which we have the records of his dynasty, that he has so improved in mind and body? Are our women and men more beautiful in body, more gifted with mental power, than the Aryans of old, from whose loins sprang the models of Pheidias?—the poet who sang in Sanskrit and in Greek, or their contemporary orators, historians, mathematicians, architects, sculptors and painters? In my own humble opinion, a negative reply must be given to this momentous question. Another question yet, and I will then bid farewell to the dream of my honoured friend, who has so charmed us with his narrative. Whilst men have still preserved their manly and intellectual strength; whilst women still are to be found that would delight the eye of the most exacting sculptor of the ancient Greek school, do we not see around us more degraded human forms than the world has ever known, not only absolutely but relatively? And do we not find these declensions from the normal standard more abundant among the civilized than the naturally barbarous and uncivilized?

And if so, why is it? Is it not because we have fallen short in our pursuit of the necessary knowledge of how to live. We have gone on living and breeding in limited areas; we have confined ourselves to favoured spots, and have spoiled them.

Man has not only spoiled many of the sites which his ancestors wisely selected as vantage grounds against the foe, the flood, and the drought; but is hourly spoiling his own form by his artificial

habits, and laying at the same time the foundation for a still further departure from a natural standard in his offspring. He is polluting the soil on which his habitations stand, he is befouling his water-courses and springs, and he is poisoning the air he breathes. He has thus created surroundings from which he can with difficulty escape; and not content with the natural disease-poisons with which the fens, the tropical lagoons and deltas of the great rivers abound he creates around his own and neighbour's dwelling the conditions that will produce newer and specific forms of disease which disfigure, disable, and kill those nearest and dearest to him.

Man has indeed made his own haunts the haunts of fevers and very magazines of organic poisons; so that the soil, which might have been a perennial source of wealth and health, has become one of disease and death.

It is humiliating to find that branches of science which have been studied for more than two thousand five hundred years should have advanced so little towards the amelioration of the evils with which man is naturally and artificially surrounded. I have said that man has spoiled many of the fair sites on which he has pitched his tent. Also that he has spoiled himself. I have hinted that there are some places which, without man's interference have been the sources of disease.

Hippocrates, who lived between two and three thousand years ago, was a physician, and the founder of medicine. He was in advance of the age in which he lived, and in many things in advance of that in which we live. This extraordinary man lived at a time when there were as his cotemporaries some of the most brilliant men the Greek Islands ever produced. He taught at that remote period how necessary it was to study the nature of the soil in relation to disease, the qualities of the waters which either sprang from it or had flowed over it. He laid down certain rules, which are applicable now to the same locality wherein he practised, as to the selection of sites, &c.; and he wrote a philosophical treatise on airs, places, and waters, which may be read now with advantage, and especially by those who think there is nothing like the learning of the nineteenth century; for they will there see clearly and distinctly shown that diseases have a geographical distribution, and that the soil on which man lives must be studied by the physician who would wish to combat successfully with disease.

The graphic description of the effect of the swampy country around the River Phasis on the dwellers there shows how keenly he observed and how highly he appreciated the facts which nature pointed out to him on the bosom of mother earth.

Hippocrates well knew that whilst the crust of the earth remained as it was in his day, whilst there were deltas, swamps, and lagoons exposed to the heat of the sun, that disease would arise; and that unless these spots were pointed out by the physicians, men would heedlessly settle there, and in the sequel pay the heavy penalty of ignorance which we are doing every day. All this knowledge had been gathered, digested, and sent forth in the most choice language that man could write centuries before the Christian era; and yet we are, in our boasted nineteenth century, piling up statistics, binding them in blue covers, placing them on our shelves, and converting these volumes that contain them into simple dust collectors. I say that this is humiliating, and certainly does not encourage us in believing that the efforts which Sanitary Institutions are making now will be followed by the anticipated success; at least in this country.

When we sum up our knowledge—I mean that modicum which we have gathered during the last century—and compare it with the gigantic mass collected, digested, and published for the public good by one man long before the Christian era, we shall be startled at its pigmy proportions. This is a time for a great tirade against some of the stupid things that man has invented. We hear of soil pipes, ventilating shafts, and every possible contrivance to keep the sewer gases out of our houses; in doing all this we are only correcting a gross blunder which the boasted intelligence of the nineteenth century committed. We poison our water, and then contrive something to prevent its being done in the future, and think how clever we are; and when we have done one or two things of this kind, we show our friends our houses, give them the name of the engineer or the architect who has rectified, as he thinks, the blunder of a former engineer or architect; we placidly fold our hands, look up contentedly to the sky, think what a wonderful thing we have done—and congratulate ourselves on a chance of living all the days of our life. I maintain that blunderingly altering the blunders of others is not Sanitary Science.

Now I hold that any Institute established for the purpose of teaching us the science of living in a cleanly and wholesome manner—as regards water, air, and soil—should first of all teach in its schools what has already been taught by such men as I have mentioned, as a wholesome restraint against the pride which a little knowledge engenders. Before we can boast of any Sanitary Science, let us be able to point to our researches on the climates, the soils, the diseases, we find at home and abroad in our vast colonies. Let the crust of the earth in various parts of the globe be thoroughly examined in its relation to diseases—recollecting that, had not man been born, there are certain spots in this earth that, produce certain specific poisons, the chemical constitution of which we know nothing. Such spots should be mapped, after having been thoroughly investigated as to soil and climate, for the use of emigrants, colonists, and those in command of our expensive but necessary soldiery—I say necessary, for whilst we have barbarous and uncivilized nations to contend with, like the Russian and Zulu, soldiers will be a necessity; and directly the word soldier is named, what a history of murderous blunders arise to appal us!

For want of studying the geology and climate of the stations to which we have consigned and still continue to consign these expensive but most necessary members of society, how many valuable lives have been sacrificed, how much treasure squandered! How many times have we sent and shall continue to send our troops to encamp upon the dried-up beds of rivers which, as Sir Ranald Martin has said, are the deadliest of sites.

How often are we to be taken aback by fever breaking out on such a rock as Gibraltar? When will the conductivity of our soils as regards heat be studied? I have said that man spoils the site which he has selected to live on. Let us only look at that map of distribution of Fever in England and Wales, and know that wherever you see the districts coloured blue in different shades, there are to be found the polluted soils which man has converted into so many beds of disease. You have only to study the geology in connection with these blue groups, and you will soon see the cause.

In conclusion, the author described the several maps exhibited by him, beginning with that on the distribution of Fever throughout England and Wales, and showing the intimate relations that existed between its prevalence and the geological characteristics of the subsoil. He also rapidly reviewed the characteristic features of his published maps of the distribution of Heart Disease and Rheumatism, Consumption and Cancer in Females. Coloured manuscript maps of the distribution of Diphtheria,* Scarlet Fever, Scrofula, etc., were exhibited and described; and lastly he dwelt upon the necessity of popularizing such facts as he had brought before the Members of the Institute, and on this account he hoped shortly to present them in such a form that the work which contained them should be a Health Guide for Great Britain, accessible to all as a book of ready reference for the active medical practitioner and the health-desiring public.

ALFRED HAVILAND, M.R.C.S.

On the Quantitative Elements in Hydrogeology.

§ DEEP SPRINGS.—A. THE AREA OF OUTCROP.

SURFACE GATHERING GROUNDS.

THE depth of rain falling upon the surface of the earth forms the basis of all calculations respecting water-supply.

Thus, the engineer who has to collect water from a mountain gathering ground works upon an actual or assumed knowledge of the mean annual rainfall, but more particularly of the lowest re-

* Whilst showing the distribution of Diphtheria he described the beautiful Geological Model of the south-east of England, by Messrs. Topley and Jordan, of the Royal School of Mines, remarking that the work which had been so well begun should be carried out by Government for the whole of the United Kingdom, and not left, as this admirable work has been, to private enterprise.

corded mean of any short period of years. A subtraction (to a certain extent the result of negative experience) is made for *evaporation*, and a further "allowance" provided for *absorption* by vegetation and porous strata. The area of the catchment basin in square miles being the only thing known with any approach to accuracy, all the other positive results required have, in the first instance, to be calculated from negative elements, and subsequently proved, in the course of years, by actual experience. About ten years ago Mr. Hawksley stated that the largest proportion of the rainfall which it had then been found possible to provide storage reservoirs for, was equal to the average rainfall of the three consecutive driest years. It would be interesting to learn whether the decade that has since elapsed has produced any more positive result than this.

Now in the above case of surface catchment basins there are few parts of these islands of which the rainfall is not now known through the twenty years' work of our President, and, thanks to his admirable organisation, the ratepayer has now some assurance that his money will not be thrown away in works that would fail to supply water (as was the case in 1868 with many gathering grounds) just when it was most wanted. It is, nevertheless, neither equitable nor creditable to the country that a few individuals should be put to a permanent expense in providing data for the good of the community at large.

SUBTERRANEAN WATER SYSTEMS.

Valuable as these rainfall records are for surface gathering grounds, they are in themselves *of no use whatever* for calculating quantities that may be drawn from subterranean water-systems. It is not upon the actual quantity of rain falling that the value of these natural reservoirs depends, but upon the quantity which passes through the soil—*i.e.*, upon the natural percolation.

PERCOLATION.

In percolation we have a net balance, after the settlement of all accounts between rainfall, the soil, and evaporation. The hydrogeologist dates his work from percolators, and bases all his calculations ultimately upon percolation. Unfortunately, however, the investigation of this most vital subject is in a very backward state, and more observations are urgently needed. But for the painstaking labours of the late Dr. Dalton, Mr. Charnock, and Mr. Dickinson, and of Mr. John Evans, F.R.S., Mr. Charles Greaves, M. Inst. C.E., Prof. Ebermayer, Mr. Baldwin Latham, M. Inst. C.E., and Messrs. Lawes and Gilbert, we should be absolutely destitute of facts upon a subject that affects the pockets of every ratepayer and every individual that seeks to obtain water by means of wells. But all these observations put together amount to a mere bagatelle by the side of those upon rainfall, made by Mr. Symons's organisation alone, to say nothing of Government observations. Yet, notwithstanding this, it is the fact that we are, as a whole, far more largely dependent upon wells for our supplies than we are upon our mountain gathering grounds.

This chapter of the subject has been fully worked out in my paper "On the Quantitative Elements in Hydrogeology. § *Percolation*," read at the meeting of the British Association at Sheffield, 1879. Percolation is, however, a *known quantity*, and a *positive* quantity which can be experimentally ascertained for every kind of soil.

HYDROGEOLOGICAL GATHERING GROUND.

Given the quantity percolating, or the *mean annual percolation*, the hydrogeologist has no further calculations to make in respect of evaporation or any other negatives, but all his work after that is done with a foot-rule, so to speak. He is concerned only with dimensions. The first of these is the area of the hydrogeological gathering ground. I must here point out the distinction between surface *catchment basins*, which are rightly so called, since they are defined and bounded by a watershed line or ridge that can be seen, and hydrogeological *gathering grounds* which are not *basins* or *catchments*, and which do not coincide either with the boundaries of permeable formations or with those of the surface system of dry basins into which these are divided.

LINES OF DIVISION. SUBTERRANEAN WATER-RIDGES. DISCHARGE BY EFFLUENT SPRINGS.

The hydrogeological gathering ground may be taken as coextensive with those basins in which the subterranean water systems are found to arrange themselves. These are divided by ridges of water, which can be felt, but not seen. Thus the area of the surface basin, or dry valley system, on the chalk, in the case of the Wandle is $52\frac{1}{2}$ square miles; but, by means of well measurements, an area of $1\frac{3}{4}$ square miles, lying, as regards the dry valley systems, within the Ravensbourne Basin, can be proved to drain into that of the Wandle, making the real gathering ground in the chalk area of the Wandle $54\frac{1}{4}$ square miles. Now, the area of contribution being known, and the percolation on this area being known, it becomes important to ascertain what is the discharge from the area by surface springs. The chalk area of the Wandle basin is drained by the springs between Croydon and Carshalton, and these springs are the source of the river Wandle. Not only the river itself, but all the principal springs have been gauged on various occasions, especially by the late Mr. Braithwaite in the spring of 1853. The springs in the Croydon and Carshalton branches, taken together, then discharged 39,156,680 gallons per day, but the mean discharge of the springs may, for the purposes of this illustration, be taken at 17,000,000 gallons per day. I believe Mr. Baldwin Latham has an elaborate series of gaugings of the river taken daily, but none are yet published.

With some reserve I quote Mr. Evans's mean annual percolation (1835-1860), 8·225 inches, as representing a fair average quantity.

Taking 8 inches as the percolation of the 54¼ square miles, that represents an annual supply of . . 7,731,465,600 gallons,
and the discharge of the springs 6,205,000,000 „
in the same time, which leaves . 1,526,465,600 gallons.

passing under the tertiary strata between Croydon and Sutton annually.

CASE A.

This is a good illustration of the simplest case which presents itself in hydrogeology of the connection between percolation, the subterranean drainage area, and the yield of that area as measured by springs, leaving the difference=the quantity, passing under the overlying impervious bed. Here, the value of the area being wholly due to the rainfall upon the area, is simply P=VSE+y, where P=Percolation; VSE the volume of the effluent springs; and y the quantity that passes under the tertiaries, and VSE=P—y. As P is measured in inches, VP will represent the volume percolating in gallons. But upon the volume percolating depends the height of the water-line H, and the difference between the highest and lowest positions of H=the *sectional area of variation.* The amount of this variation is enormously greater in the inner parts of the same subterranean basin than towards its edges, but the *mean variation* evidently bears the same direct relation to the mean percolation as the mean height of the water-line. Given the mean variation of the basin, excess over this mean indicates contribution from the parts of the basin where the mean variation falls short of the mean of the whole area, with due local qualifications. It is, therefore, most important to take daily observations of the height of the water-line in wells. Now, the whole area of outcrop of each porous stratum is made up of such little basins, each independent of the others as long as they are not artificially disturbed. Clearly, therefore, *the first object of the hydrogeologist is to map out the subterranean drainage areas.* These show where the percolation on every part of a permeable formation goes to. All the subdivisions of the chalk area from the Medway to the Itchen (Hants) have been described in my paper on "Watershed Lines."*

The knowledge of the positions of these basins is gained by determining the form of the upper surface of the water in the porous stratum. This is done by well-measurements; and, in fact, that is the principal object of well-measurements. These measurements would be useless if they were not referred to Ordnance datum. Every well-mouth has to be levelled, a work of little difficulty where the 6-INCH maps are published, but practically impossible for one individual where there is only the old 1-INCH MAP. The 6-INCH map is therefore an indispensable foundation for a perfect hydrogeological survey.

* Conf. on National Water Supply, &c., Soc. of Arts, 1879, p. 91.

WATER CONTOURS.

When the water levels have been thus determined by synchronous observations over a sufficient area, contours may be drawn by casting a series of sections, taken in all directions through the wells of observation, and passing a curve through all the points of equal altitude on these at specified intervals of elevation, such as every 10, 50, or 100 feet, according to the fulness of the data. A good map should show contours at every ten feet, and should show separate contours for the highest position to which the water rises and the lowest to which it falls, after much and little percolation.

Altitude is an element of quantity. For it will readily be seen that each successive contour describes a smaller figure than the one immediately below it and a larger figure than the one next above it. Here we see that equally with the 6-INCH ORDNANCE maps, the geological survey map is required as a basis to work upon—not the old 1-INCH map, but the 6-INCH geological map—for the water contours found by well-measurements do not by themselves inclose a space but terminate abruptly, on meeting those of equal altitude upon the upper surface of the impervious stratum below. A curve passed through these points of intersection marks the upper limit of the water system, or the line of abutment of the plane of the upper surface of the water system against that of the upper surface of the impervious stratum below. This shows the relation of hydrogeological work to geological. A hydrogeological map is a geological map and something more. While the geological survey map exhibits merely the superficial areas occupied by certain kinds of rock, the hydrogeological map shows not only the areas occupied by water, but the form of that water by contour lines, and wherever possible the contours of the top and bottom of each permeable stratum. The difference in altitude between the water contours and those of the bottom of the containing stratum gives the volume of the stratum occupied by water, while the contour lines themselves, with the "line of abutment," which marks the boundary of the water system, measure the *area* of water in the stratum above the level of each contour given. Thus, *the higher the level the smaller the quantity.* If the percolation be known, the possible yield of the area *above* each contour may easily be found.

Suppose it is in contemplation to sink a well on the chalk hills, the height of the surface should be first determined; then, from the hydrogeological map, the maximum and minimum height of the water at that point should be ascertained. The difference between the height of the surface and the minimum water line gives the minimum depth of the well. And now arises a difficult question. Suppose the well to be sunk upon a dome, where the minimum water line is at 330 feet above O.D. mean tide at Liverpool, and that the 300 contour runs round it, inclosing an area of one square mile, then if the bottom of the well be carried down to 300 feet above O.D., and the water pumped down to that level, what area will drain in towards the well? Clearly *less* than the area inclosed by the 300 contour. Therefore the yield cannot be so much as the percolation on one square mile. Again: To how much below 300 feet would it be necessary to pump the water down in order to make the space inclosed by the 300 feet contour drain in to the pumps—*i.e.*, that the yield of the well may equal the percolation on one square mile? Now the percolation on one square mile at eight inches per annum is 115,827,200 gallons, 317,334 gallons per day, and 13,214 gallons per hour. That is a very large yield, but by no means an impossible yield, for a well at the summit of the system, and under no superior pressure, as the effect of such pumping has been felt for upwards of a mile. But how much it might be necessary to reduce the column of water in the well below 300 feet to produce this I cannot say. This case is an extreme one in every way, but the simplest form in which the quantity question presents itself, and it is evident that daily gaugings of all wells, with records of the hours of pumping and the quantity pumped, would soon remove the doubt. The same reasoning is equally true of smaller areas; for instance, the 310 or 320 contour might inclose a space equal to half a square mile or a quarter of a square mile, which would give respectively, at 8 inches' percolation, 57,913,600 and 28,956,800 gallons in the year; 158,667 and 79,333 gallons per day; and 6,611 and 3,305 gallons per hour.

Now from the simple case of the contours of a dome, we may take any point on the water system in the area of outcrop such as the chalk hills. By projecting lines from this point, taking the superior contours of the system at right angles, we see what area naturally feeds towards this point. These boundary lines may take a sinuous course up to the line of abutment, or limit of the system, or they may simply run up to the line of a water-ridge. The area inclosed may be measured in square miles, and the percolation known. Then arises the question, What extra area will be caused to contribute—that is, what extra quantity will be drawn in by pumping the water down 10, 20, 30, or 100 feet? These are questions that may easily be answered if wells are regularly gauged and recorded. It must be borne in mind that elevations in the water system, whether domes or boundary water-ridges, indicate *absence of fissures* in the rock, and depressions free channels; and that water flows *from* the elevations, and *towards* the hollows. On this principle a reduction of 10 feet in the water line should have a greater quantitative value in the hollows than on the ridges. This is a necessary result from the measurement of areas of contribution above described.

There is no part of the area of outcrop of a water system in which the apparently insuperable difficulties in the way of calculation of quantity afforded by the elements of uncertainty above mentioned may not be overcome by systematic observations of the daily fluctuations of level herein recommended. A great stumbling-block in the way of such observations is the want of a suitable instrument wherewith to gauge them. Having for many years had my attention practically drawn to this point, I have constructed a very simple self-registering gauge capable of registering fluctuations to *any amount*. The apparatus will be described in a separate paper.

CONVERGING POINTS.

Now we can take the case of the converging points of a water-system—*i.e.*, the effluent springs. The volume of a spring predicates the area of contribution, assuming the percolation known *absolutely* as regards the springs flowing out by the base of a water-bearing bed, and *approximately* (but falling short of the real amount) as regards those issuing from its top. The mean volume of the springs and the mean height of the water-line are co-ordinate quantities $VH = VP = VSE + y$. Therefore the daily register of the volume of springs is an element in the quantitative value of each height of the water-line. The mean volume of a spring flowing from the base of a water-bearing bed exceeds the mean quantity that could be drawn from a well in the same basin, unless the well dried the spring up, when the yield of the well would simply be that of the spring. In the case of springs issuing from the top of a bed a well might procure a mean quantity larger than the mean flow of the springs by drying the spring, and pumping part of what naturally descends under the overlying impervious stratum. The springs of Croydon, Beddington, Wallington, and Carshalton are of this class. They are in too great volume for any one well, but it would be possible to pump, from a line of wells in the three miles, a quantity exceeding the mean volume of the springs themselves, or about 20,000,000 gallons a day. This is given merely as an illustration, and in an area where it never could be expedient to tamper with the springs. As to the *appropriation* of the springs themselves, that is a wholly different question, and as this question will at no distant future form a subject for the consideration of Londoners, I desire to express my wonderment that vested interests have been so long able to withhold some of the finest and best spring water that the world produces—and all ready to its hand—from the great city.

POSTSCRIPTUM.

The consideration of the quantitative values of the vertical fluctuations of the water-line, and of the formulæ of compound areas, such as that of a river basin in which the various streams traverse and partly mingle with various subterranean water-systems, will form the subjects of special chapters.

JOSEPH LUCAS, F.G.S.

The discussion was commenced by

DR. A. CARPENTER, who said there was much in Mr. Lucas's paper of considerable importance, and it was worthy of great attention by various classes of persons; but he must object *in limine* to one of Mr. Lucas's observations, viz., the surprise expressed by the author, that the Metropolitan authorities did not possess themselves of the springs which now supplied this district. He protested most strongly against any such appropriation. It was said by Bismarck, that as regards the Russians in Turkish territory, "*Beati possidentes;*" he would say the same as to the position of Croydon at the head of the springs of the Wandle, and he hoped that a most strenuous opposition would be offered to any Corporation or Company who at any time attempted to appropriate that which was one of the greatest treasures that the people of Croydon possessed. He was glad to hear Mr. Lucas estimate the yield of water so high. The Local Board at this time were abstracting about 2,250,000 gallons daily. Mr. Lucas says, the supply is equal to 20,000,000 gallons, so that we need be under no apprehension of failure of supply in ordinary seasons, but he thought the author had probably over estimated the quantity available. He (Dr. Carpenter), looked with dismay at the attempts which were being made on all sides to diminish the amount at the command of the Croydon Local Board. There was the Caterham Water Company; the Kenley Water Company; the Caterham Asylum, and more recently the Surrey Magistrates at the New Asylum which is to be erected in Hooley Lane, and now Mr. Lucas advises the Metropolitan authorities that they ought to come to our discomfiture. It was to be earnestly deprecated, and the Croydon people would have a right to be heard whenever the attempt was made. There was one good point in the case, it proved to the Croydon people that their water supply was worth having.

Mr. W. Barns Kinsey said, I had found great assistance in coming to a conclusion as to the water supply of a locality by drawing contours and sections as suggested by Mr. Lucas, and that in the Thames Haven well I had worked upon this system knowing that an infiltration of salt-water could not take place so long as the boring was carefully lined, and the fresh water was under a pressure that exceeded that of the sea at its mean level. I understood Mr. Lucas to say he was glad to hear of good water being obtained by going deeper for it, as his experience at Sandgate was that by going deeper he obtained salt-water. I replied that such was not my experience, as I knew very good water had been obtained in a like formation elsewhere.

A vote of thanks was then moved by the Chairman and carried. This was acknowledged by Mr. Lucas.

"Particulars of an Artesian Well at Thames Haven, Essex."

Executed for the Thames Haven Company (Limited).

The boring was commenced February 6th, 1877, by Messrs. S. F. Baker and Sons, the contractors, at a distance of about 450 yards from the river bank, and at the surface of the marsh, with a diameter of 16 in.; passing through light brown clay for a depth of 16 ft., peat 2 ft. 6 in., soft ooze 4 ft. 2 in., grey sand 25 ft. 10 in., grey clay stones and shells with thin veins of black greasy sand 2 ft. 3 in., sand and stone some $3\frac{1}{2}$ in. diameter, forming a dark gravel, 27 ft. 6 in.; making a total depth of 78 ft. 3 in. to the top of the clay.

The boring was lined as the work proceeded with cast-iron pipes, 16 inches internal diameter, having turned and bored flush socket joints; and a sample of the water was taken before the pipes touched the clay, which on analysis showed—

Total solid matter . .	3367·0	grains per gallon.
Volatile organic . .	333·0	„
Chloride of sodium . .	1190·0	„
Nitrogen as ammonia .	4·48	„
Nitrogen as albuminoid ammonia	3·10	„

The water level in the bore when at rest was at this time 5 ft. 6 in. below the level of marsh.

From 71 ft. 3 in. to 107 ft. the boring was in a stiff dark brown clay into which the 16-in. pipes were driven to a depth of 12 ft. 3 in. or 90 ft. 6 in. from the surface, the water being then pumped out and the joints of pipes examined.

From the bottom of these pipes the boring was reduced in size and lined with 3-in. diameter cast-iron turned and bored flush jointed pipes, passing from 107 ft. to 112 ft. 10 in. through sand and clay in veins; from 112 ft. 10 in. to 114 ft. through sandy clay and shells; 114 ft. to 115 ft. 6 in. sandy clay; 115 ft. 6 in. to 118 ft. 6 in. sandy clay and pebbles; 118 ft. 6 in. to 122 feet 6 inches running light coloured sand with water.

Analysis of the water gave—

Total solid matter . .	481·33	grains per gallon.
Volatile organic . .	66·60	„
Chloride of sodium . .	347·61	„
Nitrogen as ammonia .	3·50	„
Nitrogen as albuminoid ammonia	·21	„

The water level in the bore when at rest was 6 ft. 4 in. from surface of marsh. The formation was—

From 122′ 6″ to 123′ 9″ sand and oyster shells;
„ 123′ 9″ to 133′ 0″ dark sand with shell fragment;
„ 133′ 0″ to 136′ 0″ yellow ochreous sandy clay;
„ 136′ 0″ to 145′ 0″ greenish sandy clay;

From 145′ 0″ to 155′ 0″ fine green light coloured sands, firm and dry;
" 155′ 0″ to 157′ 0″ dark sand and pebbles with fragments of shells.

forming basement bed of Woolwich and Reading beds.

From 157 feet to 233 feet fine greenish sand, being a running sand full of water to 166 feet; more solid and close at 170 feet; very hard and dry at 180 feet; and from 193 feet to 233 feet a running sand with water. The water at 200 feet was salt to the taste and its level in the bore when at rest 4 feet from surface.

From 233 feet to 268 feet the boring was continued through a greenish clayey sand which at 246 feet was of a plastic nature; at 253 feet, close, dry, and firm; at 256 feet, dry but looser; 259 feet to 262 feet, bands of hard dry sandy clay; and from 262 feet to 268 feet, more or less rotten sand and clay.

At 268 feet a bed of green-coated flints was touched, forming basement bed of Thanet sands, and resting on the chalk at 268 ft. 6 in. from surface of marsh.

The boring was continued into the chalk and the 9-in. pipes driven therein 5 ft. 6 in. or a depth of 274 feet from surface, and a joint made between the 16-in. and 9-in. pipes with hydraulic cement, the 9-in. pipes being brought up to the level of the marsh.

The water was now noticed to ebb and flow with the tide to 6 inches above and 6 inches below the marsh level; but upon testing with a powerful pump passed down the bore, it was found that the Thanet sands were drawn down into the boring through fissures in the chalk, and a strong wrought-iron tube with steel shoe was therefore inserted to shut back the sand, and driven 40 feet into the chalk, a perfect joint being ensured by bringing it up to within 69 feet of the surface and filling the space between it and the cast-iron pipe with hydraulic cement which was found to run into the fissures of the chalk; the water level in the bore being also higher afterwards. An open boring 6 inches diameter was continued from this point, passing through a marly chalk to a depth of 355 feet to flint water bearing, veins at 360 feet.

A test was now made of the supply which was found to be equal to 520 gallons per hour at 100 feet deep. The level of the water at rest in the bore being $11\frac{1}{2}$ inches above marsh at high water, and the analysis showed a much better result, viz.:—

Total solids	43·00	grains per gallon.
Volatile organic	1·95	"
Chloride sodium	17·32	"
Nitrogen as ammonia	·1000	"
Nitrogen as albumenoid ammonia	·0074	"
Sulphate of lime	3·00	"
Carbonate of lime	5·80	"

At 367 feet the chalk was greyish and firm without water; at 426 feet, chalk hard and white; at 440 feet, hard chalk; at 460 feet, soft chalk with flints and water veins; at 475 feet, darker and harder chalk; at 502 feet, flint veins full of water; which being

tested gave a yield of 1300 gallons per hour at 100 feet depth for the veins at 460 feet, and of 2200 gallons per hour for those at 502 feet; the water level being also higher in the bore, or 1 ft. 2 in. above surface at high water.

The analysis gave—

Total solids	42·80	grains per gallon.
Volatile organic	·05	"
Chloride sodium	17·44	"
Nitrogen as ammonia	·0385	"
Nitrogen as albumenoid ammonia	·0046	"
Sulphate of lime	2·50	"
Carbonate of lime	5·80	"

At 506 ft. 7 in. the chalk was again grey and waterless; at 521 feet, white chalk with flints and water; at 529 feet, grey chalk, no water: at 536 feet, soft chalk with cavities, the flint veins being further apart but full of water; but from 540 to 545 feet the chalk was hard and dark, and the bottom dry and waterless; at 550 feet the chalk was softer and whiter, which changed into a white marly chalk at 566 feet, and continued to the bottom of boring at 572 feet.

The water level had now increased to 1 ft. 7 in. above level of marsh at high-water spring tides, and at low-water 7 inches below surface.

The analysis gave—

Total solids	44·80	grains per gallon.
Volatile organic	·50	"
Chloride of sodium	17·78	"
Nitrogen as ammonia	·0063	"
Nitrogen as albumenoid ammonia	none.	
Sulphate of lime	none.	
Carbonate of lime	3·50	"
Hardness before boiling	7·8°	Clark's scale.
Hardness after boiling	4·6°	"

The final analysis of the water, made by Mr. G. W. Wigner, F.C.S., London, from a sample taken on the 18th June, 1879, two hours after commencing pumping, gave the following results:—

Physical characteristics: Colour in two-foot tube, very good pale blue; suspended matter, none; smell when heated to 100° Fahr., none; taste, very slightly saline; hardness before boiling, 9·3° Clarke's scale; hardness after boiling, 5·7° Clarke's scale.

Chemical results—

	grs. per gal.
Total solid matter	43·76
Total mineral matter	42·88
Loss on ignition	·88
Chlorine as chloride of sodium	16·33
Lead and copper, none. Iron, traces	
Lime	1·84
Magnesia	1·78
Alkaline salts as carbonates	9·00

Sulphuric acid in combinations	0·17
Phosphoric acid, traces	
Nitrogen as ammonia	·0700

Nitrogen as albumenoid ammonia, none.
Nitrates and nitrites, traces only.
Oxygen absorbed by organic matter from solution of permanganate of potash, none.
Appearance of dried residue, white semi-crystalline

The microscopical results were quite satisfactory; no living organisms could be detected.

Dissolved Gases:—

Carbonic Acid	none.
Oxygen	·25 cubic inches per gallon.
Nitrogen	2·00 " "

The valuation of the water by Wigner's scale, taking the average value of London water as about 25 and the best public supplies at 10 to 15, after making suitable allowance for the source from which the salt is derived, is 21; it is therefore a first-class water.

The mineral constituents are probably combined as follows:—

Sulphate of lime	4·47
" magnesia	5·34
Carbonate of potash	8·00
" soda	6·04
Chloride of sodium	16·38

These results indicate that as regards organic matter the water is very pure, only 0·88 grains per gallon is driven off on ignition, and 0·68 of this is the combined water of the sulphate of lime. The actual organic volatile matter is therefore only 0·20 grain per gallon.

The only objectionable feature is the proportion of salt; but as the other figures of the analysis, and especially the figures of combined nitrogen, prove conclusively that the salt is not derived from organic sources, its presence is of far less moment.

The results of this analysis showed a marked improvement on the last and preceding ones.

It is a water well fitted to furnish a supply for drinking purposes, and which from the regularity of its mineral constituents will probably continue in good condition.

Although the water overflowed the surface, it was found possible to exhaust it to a depth of 80 feet by hard pumping. A pump was therefore designed of special construction that could be placed within the bore at a sufficient depth to ensure a constant supply, and at the same time be readily lifted for repairs.

The pump delivers an equal quantity of water at each stroke, and is suspended in the bore from a bed-plate attached to the head of the bore-pipe, the total depth of pump being 198 feet from the surface.

The machinery is arranged to allow for the varying level of the water, which, from overflowing the surface, is reduced to 100 feet or thereabouts, and has not been exhausted.

The valves and other details of the pump can be lifted to the surface for examination by means of suitable tackle suspended to the stand-pipes, which are attached to the pump bed-plate on each side of the boring, the engine being fitted with hoisting gear.

The pump valves are constructed of a combination of metal and india-rubber chemically united, and work without shock.

The engine and pumping machinery is enclosed in a corrugated iron building, built upon a solid concrete foundation, resting upon the surface of the marsh.

A louvred ventilator is arranged above the boring, upon hinges to enable it to be opened when the pump rods are lifted.

The engine is of the patent "Robey" type of four horse-power nominal, connected to the pump gear by a steel spur-wheel and pinion, and cuts off at one-third of the stroke. Its present duty is 26,000 gallons per day, but the water supply and machinery are equal to a considerable increase if required.

The results show the possibility of obtaining good water even when the surface and deep springs are contaminated, and are very satisfactory in a district notorious for the impurity and deficiency of its potable water.

W. Barns Kinsey, *Consulting Engineer.*

APPENDIX TO THE ABOVE.

The temperature of water at various depths taken by repeated experiments and with three lengths of pump, viz:—20 ft., 72 ft., 100 ft., to which depths the water was pumped down, gave with a depth of boring of 370 ft., 54°, 55° and 56° Fahr. respectively, the testing extending over three days, and the temparature of the air falling from 50° on the first day to 34° on the third.

With a depth of boring of 521 ft. the temperature of water was with a 20 ft. length of pump 56°, 72 ft. 58°, and with 100 ft. 58°.

With a depth of boring of 572 ft., and the highest temparature of air 80° in the shade the highest temperature of water was 58°. There was no difference between the readings at 521 ft. depth of boring and those at 572 ft., and this may be accounted for from the fact that the largest supply of water was obtained at 536 ft.

The temperature of the water in the old well which has a depth of 130 ft., taken at 8 ft. from the surface of the marsh, was 51° with an air temperature of 50°.

The temperature of water from the new well after five minutes pumping was 54°, and after working three hours 58°, the depth of pump being 198 ft. from the surface, the temperature of the air 50°, and the level of the water when commencing to pump 12 in. above surface.

A further test was made after a rest of eighteen hours, with the following results:—

Temperature of air in the shade 46° Fahr.

Temperature of water in the river at high water 48° Fahr.

Temperature of water in old well, at same time 48° Fahr.

Distance of surface of water below surface of ground in old well 7 ft. 6 in.

Temperature of water taken at testing cock of pump of new well 2 ft. 6 in. above the surface of the ground, after resting eighteen hours and emptying stand pipes and pump to that level 46° Fahr. Temperature of water at testing cock after working pump a sufficient portion of the stroke to empty it of all water above the level of 12 in. above surface of ground, at which point the water would overflow if free 50°.

The other temperatures remained as in previous tests.

Prof. WANKLYN objected to the analyses on the ground that the results proved that old and inaccurate methods must have been used to obtain them.

The CHAIRMAN, in moving the vote of thanks made some remarks on the temperature of the earth in boring Artesian Wells, and explained the precautions necessary to be taken in order to secure accuracy.

Rain collected from Roofs considered as a Domestic Water Supply.

METEOROLOGY and Sanitary Science are very closely connected. Meteorology deals with all the properties and changes of the atmosphere which surrounds our earth; and Sanitary Science has to arrive at the best means of keeping that air pure and in a satisfactory state for respiration, and to deal with the deposits from it, not only to prevent them injuring man, but also to obtain the greatest advantage from them in all ways.

One of the chief points of connection between the two sciences is rainfall; Meteorologists study the moisture in the atmosphere, its various forms and conditions, the causes which deposit it on the earth as rain, and the quantity deposited at various places. Then the Sanitarian has to take up the question of how it shall be dealt with? which naturally divides into two branches—Water Supply and Drainage, making use of the water, and preventing it doing mischief; and his chief object is so to balance the two as to get rid of it without its doing any harm, and yet to get all the good he can out of it.

We are entirely dependent on rain for our supply of water; for whether we catch the water which falls on our roofs, or obtain it from shallow or deep wells, or from streams and rivers, it is nothing more nor less than rain. The subject of Water Supply has many branches, and perhaps the most important is plenty of good water for domestic use, though the supply for manufacturing and general purposes, and for power is of vast importance, and the different interests are generally very conflicting. The agriculturist

to prevent the water standing on his land, drains it into the water-courses, which receiving it quicker than would naturally be the case, overflow and cause mischief by floods; he also manures his fields and some of the manure is washed down the drains, and instead of enriching the soil, pollutes the water. Then the manufacturer not only wants to receive the water clean and to send it away dirty, but, to get power out of it, he backs up the stream with dams and weirs, and causes floods above him; in short, every riparian owner wishes to receive the water pure and to empty into it all superfluous water, sewage, and refuse of all kinds, and to have absolute control over the river; not caring whether those above and below him are flooded, or deprived of water altogether.

When a supply of water is wanted for a large town, the first question is where is there a large rainfall within reasonable distance? Then geology plays an important part, the structure and natural products of the gathering ground affecting not only the quality and quantity of water that can be made available, but also the cost of the necessary works and reservoirs. For the use of towns the water can be brought in bulk, and having only to be distributed over a small area the cost though great can be easily met, but in small villages and rural districts the cost of distribution would be so great that a supply in this manner is altogether out of the question. In these districts, however, the importance of a sufficient quantity of pure water for domestic purposes is very great, and seems to be only equalled by the difficulty of obtaining it. The usual sources of supply are the small streams and shallow wells; the streams are scarcely ever pure enough for drinking, and the wells are very frequently much too near cesspools and house-drains, to say nothing of the miscellaneous organic matter with which surface water must necessarily be polluted. This is not all; one well generally supplies several cottages, and the distance which the water has to be carried, prevents it being used in anything like sufficient quantity for thorough cleanliness; and in hot and dry weather when a plentiful supply is more than ever needed, the well often runs dry, or at least, the scarcity of water causes frequent quarrels.

Perhaps the simplest solution of the difficulty is storing the water which falls on the roofs of houses, if a sufficient quantity can be obtained in this manner, and the object of my paper is to consider this question.

The average rainfall over the British Isles varies from about 20 inches to nearly 200 inches per annum. The largest amounts being recorded in the English Lake district, and in the mountainous districts of Wales and Scotland; and the smallest in the eastern and midland counties of England. I have selected four fairly representative stations with average rainfalls of approximately 22, 25, 35, and 45 inches, on which I have based my calculations. Stations where the fall is much above 45 inches are only found in mountainous districts which are generally rocky, and consequently there is no difficulty in obtaining a supply of water from the streams which are numerous, and in such districts usually sufficiently pure. The two average falls, 22 inches and 25 inches, may appear rather near each other in amount, my reason for adopting them was that the 22 inches was the lowest satisfactory average I knew of, obtained from a sufficiently large number of years, and 25 inches represents the fall over a larger part of the country than any other amount.

In dealing with my subject, I shall consider more particularly the supply of labourers' cottages; for although pure water is as necessary to the middle and upper classes of the community, they have the matter more in their own hands, and can, as a rule, meet the necessary expense of procuring a good supply.

Taking the average size of a cottage as 15 ft. by 20 ft., which I think is not far from correct, the average yield of water for a year, with a mean rainfall of twenty-five inches, would be 3,900 gallons, or nearly 10·7 gallons per day, but this is without allowing anything for loss in collecting, which is considerable. From measurements of the flow of water from a tiled roof in average condition, I find that about twenty per cent. is lost. First, there is the water absorbed by the tiles; then a considerable quantity is held between the tiles by capillarity; and, lastly, some is lost by splashing off the edges of the roof and out of the gutters. On a slated roof, I believe the loss might be reduced to between five and ten per cent.

Then, also, we must not calculate the supply only from the average rainfall, but from the fall in a dry year. Thus, at a station with a mean annual rainfall of twenty-five inches, the amount in the driest year is about seventeen inches. This would yield 2,653 gallons. Deducting twenty per cent. for loss, 531 gallons leave as available supply 2,122 gallons, or little more than 5·8 gallons per day, which would be altogether inadequate for the use of four or five persons — the presumed number of the inhabitants of the cottage.

With a mean rainfall of thirty inches, we should have an average supply of 10·3 gallons per day, and in the driest year 6·9 gallons.

With a 35 in. rainfall 12·0 gallons, and 7·7 gallons per day
„ 40 „ „ 14·5 „ „ 10·8 „ „
„ 45 „ „ 16·4 „ „ 13·1 „ „

I have not been able to find anywhere a statement of the requisite quantity of water per head, per day in rural districts. In towns the quantity varies from about twelve gallons to about fifty gallons; but there can be no comparison, as in towns a large proportion goes for trade supply and for general Sanitary purposes; a great deal is wasted by bad fittings; and the amount used for water-closets, which are almost unknown in country cottages, is, I believe, considerably more than half the quantity delivered to each house.

I think there can be little doubt, that a cottage with an average supply, of twelve gallons per day of pure water close to the house, would be considerably better off than nine-tenths of the English cottages in their present condition; but this could only be obtained from a tiled roof in places where the mean rainfall was thirty-five inches and upwards. In places where the rainfall was less, this

method could only be adopted with satisfaction as a supplemental supply, or for potable water where there was another supply for cleansing purposes.

It is of considerable importance that the water collected on roofs be properly stored. A great deal might be said about the objection to storing in wooden butts, or cisterns of any kind above ground which are often exposed to the sun, and are liable to receive various impurities, the water becoming unfit for consumption after a very short time, and I believe it is from this cause that a great deal of the prejudice against rain-water as a beverage has arisen, for if properly stored it is probably the most wholesome of all waters. The best receptacle is an underground tank or well, bricked at the sides and bottom, and lined with about half an inch of Portland cement, to prevent any possibility of loss from leakage or pollution from the infiltration of impure water from the surrounding ground; the top should be domed over leaving a man-hole, so that the tank may be occasionally cleaned; the man-hole should be covered with a slab of paving stone laid in mortar, to prevent worms or insects getting in and polluting the water. The pipes from the roof to the tank where they pass underground should be of glazed earthenware, and the joints made with cement, so as to be both watertight and impregnable to insects and other polluting matter from the outside. They should not go straight into the tank, but into a small receptacle beside it, in which any dead leaves or other matter carried down from the roof would be intercepted, so as not to reach the tank and decay in the water. This receptacle should be made with a closely-fitting movable cover, so that it could be occasionally cleaned, which would aid materially in keeping the water pure. The tank should also have a waste-pipe to allow any surplus water to escape, the end of which should be covered with a piece of perforated zinc or copper wire gauze, to prevent frogs, mice, or other vermin having access to the water. A tank carefully constructed in this manner will not require cleaning more than once in two or three years.

The size of the tank is perhaps the next point for consideration; to insure a regular daily supply proportionate to the yearly fall, the tank must be of sufficient capacity to store all the water that falls during the wet periods of the year, for if during the spring some of the heavy rains run to waste, the water kept in store will not be adequate to meet the daily demand during the dry summer weather, for it is evident that anything deducted from the yearly amount of rain even during the wettest season must of necessity reduce the average daily supply that it is capable of yielding. I have, therefore, calculated the requisite capacity of the tank from the surplus yield of water during the three wettest months, and find that for a cottage 15 ft. by 20 ft.—the size on which I have based all my calculations—with a rainful of 20 inches the tank would require a capacity of 150 cubic feet, or 5 months' supply

with a rainfall of 25 inches,	200	„	5	„	„	
„	„ 35 „	235	„	4	„	„
,	„ 45 „	250	„	3	„	„

The decrease in the proportionate size of the tank with larger rainfalls is due to the different relation which the wet periods in dry districts bear to those periods in wet districts; that is to say, that where the average rainfall is 20 inches, the fall during the wettest three months will be about 75 per cent. of the mean annual fall; while at stations where the mean rainfall is 45 inches, the wettest three months will be only about 50 per cent. of the annual fall. Or, to put it very simply, at wet stations the fall is more evenly distributed over the year.

The cost of tanks such as I have described is not great, and would not exceed one shilling for each cubic foot of capacity, that is a tank holding 100 cubic feet would cost £5, and so on. When a storage capacity of more than 200 cubic feet is required, it will be found advantageous to make two or more tanks rather than one large one.

In the foregoing I have worked on an average condition of things and of course the results are averages, and there are various disturbing elements; as before stated, I have taken as my basis a cottage having an area of 300 square feet with a tiled roof in fair condition, the inclination of the roof being about 35°. I do not think the inclination of the roof has much effect, for though a steep roof would catch rather less water, it would run off more freely and less would be held between the tiles by capillarity; of course with a very flat roof the conditions would be reversed. On a slated roof there can be no doubt that the loss would be less, and, as before mentioned, need not exceed 10 per cent.

I think the most important element is the position and bearing of the house, for if a house has a large expanse of steep roof facing a wet wind, it will, undoubtedly, catch more than the average, especially if it is in an exposed situation. I believe, as a general rule, a flat roof will catch most water in a sheltered position, and a steep roof in an exposed position, if it presents a fair proportion of roof to the wet winds.

It is hardly necessary to state that in calculating the yield of water from any roof, the area of the ground covered by the roof should be taken, and not the area of the roof itself.

The question of Water Supply is perhaps engaging more attention now than it has ever done before, and I hope the few facts I have given on what appears to me one of its most difficult branches, and at the same time one that seems most likely to be overlooked—the supply of country cottages—have not been altogether useless or uninteresting.

In conclusion, I should like to express my thanks to the President, Mr. Symons, for allowing me the free use of his rainfall records which were so essential for the compilation of this paper.

APPENDIX.

Table showing the daily yield of water from roofs of various sizes with varying rainfalls.

Area of House 10 ft. × 20 ft. or 200 sq. ft.

Mean rainfall.	Loss from evaporation, &c., per cent.	Requisite capacity of tank.	Mean daily yield of water	Mean daily yield of water in wettest year.	Mean daily yield of water in driest year.
in.		cubic feet.	gallons.	gallons.	gallons.
20	25	100	4·3	6·7	3·2
25	20	135	5·7	7·5	3·9
30	20	145	6·8	9·4	4·5
35	20	155	7·9	11·0	5·0
40	15	165	9·7	13·1	7·2
45	15	170	10·9	14·2	8·8

Area of House 15 ft. × 20 ft. or 300 sq ft.

Mean rainfall.	Loss from evaporation, &c. per cent.	Requisite capacity of tank.	Mean daily yield of water.	Mean daily yield of water in wettest year.	Mean daily yield of water in driest year.
in.		cubic feet.	gallons.	gallons	gallons.
20	25	150	6·4	9·9	4·8
25	20	200	8·6	11·3	5·8
30	20	225	10·3	14·2	6·9
35	20	235	12·0	16·7	7·7
40	15	245	14·5	19·6	10·8
45	15	250	16·4	21·4	13·1

Area of House 20 ft. × 25 ft. or 500 sq. ft

Mean rainfall.	Loss from evaporation, &c., per cent.	Requisite capacity of tank.	Mean daily yield of water.	Mean daily yield of water in wettest year.	Mean daily yield of water in driest year.
in.		cubic feet.	gallons.	gallons.	gallons.
20	25	250	10·7	16·6	8·0
25	20	335	14·3	18·7	9·7
30	20	375	17·1	23·6	11·4
35	20	390	19·9	27·7	12·7
40	15	405	24·2	32·8	18·0
45	15	415	27·3	35·7	21·8

Area of House 20 ft. × 50 ft. or 1000 sq. ft.

Mean rainfall.	Loss from evaporation, &c. per cent.	Requisite capacity of tank.	Mean daily yield of water.	Mean daily yield of water in wettest year.	Mean daily yield of water in driest year.
in.		cubic feet.	gallons	gallons.	gallons.
20	20	500	22·8	30·1	15·5
25	15	665	30·3	40·0	20·6
30	15	740	36·4	50·3	24·4
35	15	785	42·4	59·0	27·0
40	15	815	48·4	65·3	36·3
45	15	835	54·4	71·3	43·5

Area of House 25 ft. × 80 ft. or 2000 sq. ft.

Mean rainfall.	Loss from evaporation, &c. per cent.	Requisite capacity of tank.	Mean daily yield of water.	Mean daily yield of water in wettest year.	Mean daily yield of water in driest year.
in.		cubic feet.	gallons.	gallons.	gallons.
20	20	1010	45·6	60·2	31·0
25	15	1330	60·6	80·0	41·2
30	15	1480	72·7	100·5	48·7
35	15	1570	84·8	118·0	54·0
40	15	1630	96·7	130·6	72·6
45	15	1670	108·8	142·7	87·1

Particulars of Tank or Well

Capacity.		Dimensions.			Approximate cost.
Cubic feet.	Gallon.	Square, length of side.	Circular, diameter.	depth.	
		ft. in.	ft. in.	ft in.	£ s.
100	624	4 0	4 6	6 6	5 0
125	780	4 0	4 6	8 0	6 5
150	936	4 6	5 0	7 6	7 10
175	1092	5 0	5 9	7 0	8 15
200	1248	5 0	5 9	8 0	10 0
225	1404	{ 4 0 4 0	4 6 4 6	7 0 } 7 0	11 5
250	1560	{ 4 0 4 0	4 6 4 6	8 0 } 8 0	12 10

H. Sowerby Wallis, F.M.S.

Since writing my paper I have seen an article in the *Sanitary Record*, of Oct. 20th, by J. M. Fox, M.R.C.S., "On the Supply of Water to Rural Districts and the Public Health (Water) Act," to which I should like to refer. After considering the general powers given to rural authorities by this Act, the author, speaking of water, says:—

"The practical questions it appears to me are (1) as to sufficient quantity, and (2) the limitation of cost specified in the Act."

"Much misapprehension, I have been led to think, exists as to the quantity of water consumed in rural households. Accustomed to the large estimates of town requirements, including many purposes for which water is necessary there, but finding no corresponding use in the country, it strikes us with astonishment that three gallons per head per day is an outside estimate for a village consumption. And yet I have proved this by water supplied to villages through a meter again and again."

"Taking the usual average, therefore, of five and a half persons to a cottage, the quantity required for such a dwelling would be about 13¾ gallons." The quantity I considered sufficient in my paper, 12 gallons, is therefore rather small. "Now a cottage, with its outbuildings, says Mr. Wheeler, M.INST.C.E., covers about 500 square feet of ground." I think this is too large, for, although many cottages with their outbuildings undoubtedly cover 500 square feet, a much larger number are considerably smaller, more especially those built in blocks of three or four, and the outbuildings, as a rule, are so rough and the roofs so bad, that the amount collectable from them would be too small to repay the trouble of collection.

"Taking the rainfall at 22 inches per annum, a minimum estimate throughout the country generally, a slated roof will yield 5,700 gallons per annum, equal to a daily supply of 15⅓ gallons, or very nearly three gallons per head per day." In this calculation only 2·6 per cent. is allowed for loss, which is not nearly sufficient even with a slated roof.

"But the rainfall is, of course, unequally distributed throughout the year. And this brings us to the second question of cost. The cost specified in the Act, at which an authority may make a compulsory order for water-supply to a house is thus defined:—'Not exceeding a capital sum, the interest on which at the rate of five per cent. per annum, would amount to twopence per week.' This represents a capital outlay of £8. 13s 4d, and such, indeed, might as well have been stated in the Act with less circumlocution."

"It is a very unusual drought that extends over two months. But it has become a rule amongst engineers that all storage receptacles, be they reservoirs for towns or tanks for cottages, should not contain less than seventy-eight days' unrenewed supply. Thus a tank for a cottage, covering 500 square feet, would require to be 6 ft. 6 in. in diameter, and 6 ft. deep, and to hold 1200 gallons." Though seventy-eight days' storage may be sufficient in the case of a reservoir for a town where, in the wettest season of the year, a large quantity of water is allowed to run to waste, it is not sufficient, in the case of a cottage where it is necessary to save all the available rainfall, for although we never have seventy-eight days without rain we frequently have 200 or 250 consecutive days with considerable less than the average fall.

"The cost of such tank is estimated at 1½d per gallon. Larger tanks may be reckoned at 1d. per gallon. Hence, there is economy in making one tank serve for two or three cottages." This estimate is I believe too low for a properly constructed tank such as I described, but the estimate I gave of about 2d per gallon is, perhaps a trifle high. I also think that it is a mistake to make one tank serve for two or three cottages, for though it is undoubtedly cheaper, the increased size renders the brickwork much more likely to sink and crack, and allow the infiltration of foul water from the surrounding ground.

"At this rate, the cost of the water supply from heaven, independently of all chances afforded by the soil, and stored for permanent use, would be £6. 5s per house, or £2. 8s 4d within the limit laid down by the Act."

"From what I have before said, it follows that I cannot agree with this conclusion, for as I consider that a larger tank would be necessary, the cost would, of course, be greater, and also Mr. Fox makes no allowance for the cost of gutters and pipes, which would have to be provided in nearly all cases. I am, therefore, afraid that a supply in this manner could not be made compulsory, as the cost would, I believe, slightly exceed the limit laid down by the Act."

H. SOWERBY WALLIS.

Mr. W. B. KINSEY then said Mr. Wallis did not appear to have made any provision for filtering the water before storing it, which, after the remarks by Mr. Symons as to the washing of the air by rain, would seem to be necessary.

MRS. AMELIA LEWIS observed that the paper just read was of the highest interest, though it had been put forward in such a quiet and unobstrusive manner. We were as yet in infancy with our knowledge what to do with the natural water supply of the world, and little understood the relations which it bore to our necessities. Rivers had lost their volume, it had been said, by our ignorant waste of trees; while districts had been deprived of natural moisture by over drainage, and droughts been produced by neglect of vegetable life. The saving of rainfall in this instance would benefit thousands, who could not participate in the artificial supply of towns; it was certainly desirable that this natural supply should not only be taken care of, but kept pure by sanitary arrangements. The plan advocated by Mr. Wallis seemed very feasible, only—who was to bear the expense? Mrs. Lewis was afraid that it belonged to the good things, that were a long time coming. Still, nothing could be better than calling attention to the great want of water among cottagers, miles away from towns; and only those who had experienced the shortcomings of this supply in agricultural districts, as she had herself, could understand the vast importance of using the natural supply in a healthy manner for the well-being of a large part of our population. There could be no doubt that Mr. Wallis deserved the very highest praise for bringing this subject in so succinct a manner before this Section of the Sanitary Congress.

Mr. Baldock considered that Mr. Wallis had rendered a great service to Sanitary Science, especially on behalf of the poorer section of the community, in his suggestions for providing them with an improved water supply. Nothing could be worse than the sources from which, at present, most houses in poor localities, and cottages in country districts, derived their water, and Mr. Wallis' proposal for catching and carefully storing the rain-water from the roof, seemed to him (Mr. Baldock) to exactly meet the case of houses in out-of-the-way places and at considerable elevations, where a regular supply would never be likely to come; it reminded him of a very similar plan adopted by a friend many years ago, of having a large underground tank for receiving the rain-water, from which it was pumped to wherever it might be required. Mr. Baldock hoped that Mr. Wallis, and others, would continue their efforts in this direction, with a view to the more general adoption of this system.

Mr. T. H. Porter, Mr. Hill and Dr. A. Carpenter also took part in the discussion.

In reply, Mr. Wallis said the first question raised was respecting filtration; this was undoubtedly advantageous, but not by any means necessary; in the case of a house with which he was acquainted, supplied in this manner, it was impossible to ascertain by tasting or ordinary examination whether the water had been filtered or not, and he was afraid that if filters were supplied to labourers' cottages, in the majority of cases they would not be used.

It was suggested that as a grand national water-supply had been proposed by the Society of Arts, and powerfully supported, it was unnecessary to consider the question; but if the inhabitants of rural districts were to be dependent on their present supplies until that proposition was accomplished, he was very sorry for them. The cost of a water-supply to cottages must of necessity fall directly on the owners, for the occupiers very seldom had sufficient capital, but by a very slight addition to the rent a good interest might be secured on the outlay, and would, he believed, be readily paid.

He thought no other point occurred in the discussion to which it was necessary to refer, but he wished to thank the meeting very sincerely for the kind attention with which his paper had been received and for the vote of thanks.

On some of the apparent influences of the Weather upon the prevalence or otherwise of certain classes of disease.

(Illustrated by Weather Charts.)

Having taken a small share for some years past in the compilation of the mortality returns of the Croydon district for the Local Board of Health, by the contribution of the meteorological element, I venture to submit a short paper on some of the apparent influences of the weather upon the prevalence or otherwise of certain classes of disease.

The diseases which I have illustrated are those of the zymotic and the pulmonary class. To facilitate the study of the subject, I have constructed from the Mortality Tables of Croydon, as first published by the late Dr. Westall and afterwards by Dr. Philpot, the Medical Officer of Health, a Table calculated to show at a glance both the annual and the quarterly death-rates from those diseases, also the mean temperature and rainfall for the same times, and extending over a period of 14 years from 1865 to 1878.

In the first place I divide the period of time into equal portions of 7 years each, and compare the averages of one with the other; so that we see what progress has been made, if any, in the control of preventible diseases, and what differences of meteorological phenomena may have been exhibited during each term.

I find that the annual death-rate from *all* causes for the first 7 years, 1865-71 was 20·51 per 1000 living, and for the second 7 years, 1872-78, 18·62, thereby clearly showing an improvement to the extent of 2 per 1000; and the improvement is pretty equally divided amongst the four quarters of the year, the figures being respectively 22·8, 19·1, 20·1, and 21·4 for the first 7 years, and 20·7, 17·4, 18·4, and 18·5 for the second.

I next take the 7 principal zymotic diseases and I find that the average number of deaths per year for the first period was 183, or a rate of 3·6 per 1000, and for the second period 176, or a rate of 2·8, thus showing another improvement, though slight.

Taking the average number of deaths from zymotic diseases per quarter, I find there is a slight increase in the third quarter, the numbers for the first period being 44, 39, 56, and 44 respectively, and those for the second 39, 37, 59, and 41: in the three remaining quarters there is a diminution.

The annual mean temperature of the first period was 49°97 and of the second 50°67 or 0°7 higher.

The mean temperatures of the first and fourth quarters of the year were in the second period as much as 2°3 and 1°2 respectively higher than in the corresponding quarters of the first period. The mean of the second and third quarters remaining nearly stationary.

The mean annual rainfall of the first period was 26·61 inches, and of the second 28·52 inches, or 1·91 inch more.

The mean annual rainfall for the whole period of 14 years was 27·56, or 1·5 of an inch above that of the average generally ascribed to it.

The mean temperature for the whole period was 50°3, or the same as is usually quoted.

The first and third quarters of the year in the second period show a diminution in the amount of rainfall, but the second and fourth an increase; the latter to the extent of 2¼ inches.

Now, taking these averages into account, it would appear that, as the zymotic rate was higher on an average when the temperature and rainfall were lower, and *vice versâ*, and that the general death-rate at the same time was affected in the same way, high temperature and large rainfall were most conducive to health.

Perhaps if we take a few instances, we may be convinced of the fallacy or otherwise of the argument, or we may find it clearly proved that no certain rule can be found to apply, or that weather has nothing at all to do with it.

In the first quarter of the first year 1865 we find that the number of zymotic deaths was only 16, and less by 7 than in any other first quarter of the 14 years.

The temperature was *very low*, being only 36·5 degrees, and lower by 1⅓ degrees than in any other quarter of the 14 years.

The rainfall was 6·32 inches and just above the average of the previous 10 years.

Unfortunately, I have been unable to obtain a return of the number or rate of the pulmonary diseases for that or the following year, but the deaths from those causes in the first quarter were large; for, though the zymotic rate was very low, the general death rate was high.

Turning now to the fourth quarter of the same year, we find a great contrast, the number of zymotic deaths was 90, or at an annual rate of 8·8 per 1000, and has never been equalled in any quarter since.

Of the deaths, 22 were from measles and 38 from fever.

The mean temperature was 44°9 degrees, and above the average; and the rainfall very large, 11·36 inches, 7 inches of which in October followed a rainfall of one day only in September, the total rainfall for the year being 30·51 inches.

It will be advisable to look at the first quarter of the following year, 1866, which was also one of large rainfall, 11·70 inches, and an average mean temperature, and we find 71 zymotic deaths, 22 of which were measles and 28 fever, contrasting strongly with the first quarter of 1865.

High as the zymotic rate was, still it showed a falling-off of 20 deaths as compared with the previous quarter, and the remaining quarters of the year had a rapidly decreasing mortality from that class of disease, notwithstanding that the rainfall of the year was again very large, being over 32 inches.

The mean temperature of the second and third quarters of the

year 1865 was high, with heavy rains, long periods of drought, and an increasing zymotic death-rate; whilst the mean temperature of the second and third quarters of 1866 was low, with a large rainfall and a decreasing zymotic rate.

But the years of deficient rainfall as a rule show the highest death-rate from zymotic disease.*

The highest death-rate from those causes in any of the 14 years occurred in 1865 and 1868, and was 4·56 and 4·3 per 1000 respectively. The temperature of 1868 was the highest in the series, but the rainfall was very low, measles, scarlet fever, enteric fever, and especially diarrhœa being each strongly represented.

In 1869 and 1870 the zymotic death-rate was high, the prevailing complaints being scarlet fever in all the quarters of each year, and diarrhœa in the third of each.

In 1871, in addition to scarlet fever came an epidemic of small-pox, of which 59 deaths occurred in the first three quarters, and none in the fourth. Diarrhœa was also prevalent in the third quarter.

In each of these years, as in 1868, the rainfall was low, and in 1870 very low, the temperature generally ranging high during the summer months.

In 1872, a year with high temperature and a very large rainfall, 35·27 inches, the zymotic rate was much lower than in the previous four years, notwithstanding that measles and whooping-cough were epidemic.

Following this year of excessive rainfall came 1873 with 10 inches less rain, and less than an average temperature, and we find the zymotic death-rate lower than in any other year of the series, being only 1·3 per 1000; the general death-rate was also the lowest, being only 16·93.

During the years 1874, 1875, and 1876, the zymotic rate rose to 2·5, 3·6, and 3·5 respectively, the rainfall being low and the temperature high.

In 1875 occurred a visitation of enteric fever, which had two periods of great activity, as though there were some disturbing causes at work which only required to be removed that the results might cease. The mean temperature was high and the rainfall exceptionally heavy during short periods.

In 1876 and 1877 zymotic diseases were still prevalent, but in 1877 enteric fever died away, the rainfall being large and continuous, and the temperature high.

In 1878, diphtheria, whooping cough, and infantile diarrhœa were prevalent, no less than 60 deaths from diarrhœa, 55 of which were

* In the case of 1865, although the total rainfall for the year was large, being over 30 inches, still it was remarkable for the irregularity of its distribution, and for the smallness in number of its rainy days, for instance, there were but three days' rain in April, giving only 0·17 of an inch, whilst eleven days in May gave 3·40 inches, one day of which having a fall of 1·20 and another 1·10 of an inch during thunder storms. Again, in September there was but *one* day on which it rained, to the amount of 0·27 of an inch, whilst in October there were twenty-three days of rain to the amount of 7 inches.

of infants under one year old, occurring in the third quarter. The atmosphere of that quarter was very close and thundery, with large and heavy rainfall following upon a very large spring rainfall.

Looking at all the circumstances of the case, it appears that years mostly prevalent with zymotic disease are those years in which there have been long periods of dry weather with occasional heavy rains, as in 1865, 1868, and 1870. The chart for the year 1870 I have brought for your inspection.

Those years which have the greatest number of rainy days being those with the lowest zymotic death-rate, as in the present year; the chart for which is before you for comparison with that of 1870.

In 1870 the temperature of the summer was high, and the rainfall very deficient, quite a drought having prevailed, but still there were occasional heavy rain storms with long intervals of drought between, in that year the zymotic rate was high from scarlet fever and diarrhœa.

In 1879 we have had almost continuous rain, and often very heavy, but there have been no periods of drought, and the temperature has been low, the zymotic rate has consequently been low; diarrhœa has been conspicuous by its absence, the low temperature and moist atmosphere being alone responsible for the generally high death-rate, which was principally caused by the great mortality from respiratory diseases.

The rainfall of the present year to the end of September has been 28·03 inches, or 10 inches more than the average, and 2 inches more than the average for the whole year and the number of rainy days 159, or 58 in excess.

The rainfall of 1870 for the same period was but 13·11 inches or 15 inches less, and the number of rainy days 78 less.

This year is the third instance since 1865 of an almost continuous rainfall, resulting in a low zymotic death-rate.

There is one point more I should like to touch upon, and that is, the great difference between the nature of the rainfall of the last four or five years and that of previous years. The falls of rain are much heavier and more frequent than formerly, and I think that much of the unusual prevalence of fever since 1874 has been caused by the frequent exceptionally heavy rains, especially those which occur at night; when, unless there is a distinct and ample provision for storm water, it must enter with great force and volume into the sewers, the lower parts of which become flooded, at the same time that the ventilators in the streets are choked; and forcing the sewer gas to make its escape to the higher levels, it enters the houses placed ready to receive it.

Heavy rains in the daytime do not so much matter, for the houses are open, and it is very seldom that a heavy rain occurs at night which might be called sufficient to produce an epidemic of fever, and which should be at the rate of an inch in an hour.

Such a rain occurred soon after midnight on the 24th of September, 1875, during a violent thunderstorm, when 1·13 of an inch of rain fell in an hour; and as at that time the storm-water was not

YDON.

Year	ANNUAL DEATH-RA				EMPERATURE. MEAN					RAINFALL.				
	Quartorly.				Quartorly.				Year	Quartorly.				Year.
	1st.	2nd.	3rd.	4th	.	2nd.	3rd.	4th.		1st.	2nd.	3rd.	4th.	
						°	°	°	°	Inches.	Inches.	Inches.	Inches.	Inches.
1865	21·3	18·1	20·8	25·6	5	55·0	61·9	44·9	49·6	6·32	5·56	7·29	11·34	30·51
1866	26·9	20·4	16·8	20·9	7	53·9	60·0	45·1	49·9	11·70	7·26	8·71	4·71	32·38
1867	21·0	16·6	15·6	19·9	2	55·1	60·0	41·7	49·1	6·94	5·12	8·86	4·12	25·04
1868	21·0	22·2	21·4	25·2	4	57·7	64·1	44·4	51·8	6·61	3·03	6·92	8·02	24·58
1869	21·1	19.2	22·7	20·7	7	53·5	61·7	44·2	50·3	6·89	5·70	5·22	7·57	25·38
1870	23·9	18·2	19·9	19·9	8	55·3	61·6	42·2	49·5	1·99	1·48	6·64	9.16	22·27
1871	21·3	19·3	20·3	17·7	0	52·9	61·8	42·6	49·6	5·56	6·91	8·70	3·37	24·54
1872	20·1	17·1	19·8	15·6	7	53·9	62·0	46·3	51·8	8·74	6·24	7·16	13·13	35·27
1873	19·1	17·3	16·1	16·2	6	53·4	60·9	41·8	49·7	7·32	5·25	7·10	6·01	25·71
1874	19·5	18·4	16·8	19·4	2	54·3	62·0	42·8	50·3	3·53	5·27	6·08	9·22	24·10
1875	24·1	20·0	19·4	23·4	8	54·6	61·6	44·5	50·4	5·18	4·95	8·30	8·44	26·87
1876	22·1	15·8	20·8	17·5	7	53·5	62·6	47·8	51·2	5·66	3·59	6·16	11·41	26·82
1877	21·0	18·8	15·6	16·9	1	53·8	59·9	45·5	50·6	9·38	7·35	6·93	8·52	32·18
1878	18·7	14·3	20·4	20·8	2	56·4	61·9	42·1	50·7	3·73	10·70	7·02	7·26	28·71
1879	22·5	18·3			0	51·4				6·56	10·08			
Avg. of 1st 7 Yrs.	22·8	19·1	20·1	21·4	·7	54·8	61·6	43·6	49·97	7·00	5.24	7·48	6·90	26·61
Avg. of 2nd 7 yrs.	20.7	17·4	18·4	18·5	·0	54·3	61·6	44·8	50·67	6·22	6·19	6·96	9·15	28·52
Avg. of 14 Yrs.	21·7	18·2	19·2	19·9	·8	54·5	61·6	44·2	50·32	6·61	5·71	7·22	8·02	27·56

To face page 220.]

G. Corden.

ear old, occurring in the third quarter. The
rter was very close and thundery, with large
owing upon a very large spring rainfall.
circumstances of the case, it appears that
t with zymotic disease are those years in
long periods of dry weather with occasional
65, 1868, and 1870. The chart for the year
or your inspection.
have the greatest number of rainy days
lowest zymotic death-rate, as in the present
ich is before you for comparison with that of

erature of the summer was high, and the
quite a drought having prevailed, but still
heavy rain storms with long intervals of
that year the zymotic rate was high from
hœa.
ad almost continuous rain, and often very
been no periods of drought, and the tempera-
e zymotic rate has consequently been low;
spicuous by its absence, the low temperature
being alone responsible for the generally high
principally caused by the great mortality
ses.
resent year to the end of September has been
ches more than the average, and 2 inches
for the whole year and the number of rainy
ess.
for the same period was but 13·11 inches or
number of rainy days 78 less.
d instance since 1865 of an almost continuous
low zymotic death-rate.
more I should like to touch upon, and that is,
tween the nature of the rainfall of the last
that of previous years. The falls of rain are
e frequent than formerly, and I think that
revalence of fever since 1874 has been caused
tionally heavy rains, especially those which
unless there is a distinct and ample provision
st enter with great force and volume into the
s of which become flooded, at the same time
the streets are choked; and forcing the sewer
pe to the higher levels, it enters the houses
e it.
daytime do not so much matter, for the houses
ery seldom that a heavy rain occurs at night
ed sufficient to produce an epidemic of fever,
t the rate of an inch in an hour.
d soon after midnight on the 24th of Septem-
violent thunderstorm, when 1·13 of an inch of
and as at that time the storm-water was not

ABSTRACT OF DEATH-RATES AND METEOROLOGY AT CROYDON.

Year	Annual Death-Rate. Quarterly. 1st.	2nd.	3rd.	4th	For the Year.	Zymotic Diseases. Total of each per year. S.P.	M	Sct.F.	Dipth.	Who.C.	F.	D.
1865	21·3	18·1	20·8	25·6	20·97	6	21	27		21	52	47
1866	26·9	20·4	16·8	20·9	21·18	5	32	19		29	51 Enteric	25
1867	21·0	16·6	15·6	19·9	18·08	8	1	19		18	15	30
1868	21·0	22·2	24·4	25·2	21·99	1	39	41 Sct. Fevr.		35	36 Enteric.	55
1869	21·1	19.2	22·7	20·7	20·93	1	15	86 Sct. Fevr.		24	19	41
1870	23·9	18·2	19·9	19·9	20·46	11	14	88 Sct. Fevr.		33	18	52
1871	24·3	19·3	20·3	17·7	20·00	59 Epidemic.	16	32		32	22	63 Epidemic.
1872	20·1	17·1	19·8	15·6	18·03	5	50 Epidemic.	10		36 Prevt.	24	41
1873	19·1	17·3	16·1	16·2	16·93	5	5	10		14	9	36
1874	19·5	18·4	16·8	19·4	18·01	..	65 Epidemic.	18		21	17	28
1875	24·1	20·0	19·4	23·4	21·61	1	..	38	7	45 Epidemic.	90 Enteric.	50
1876	22·1	15·8	20·8	17·5	19·07	13 Prevt.	13	71 Epidem.	26 Prevt.	21	34 E—Prevt.	46
1877	21·0	18·8	15·6	16·9	18·03	29 Prevt.	30	5	43 Prevt.	14	25	32
1878	18·7	14·3	20·4	20·8	18·57	4	14	15	36 Prevt.	39 Prevt.	20	63 Prev. Infts. (3rd Qr.)
1879	22·5	18·3										
Avg. of 1st 7 Yrs.	22·8	19·1	20·1	21·4	20·51	12	20	46		27	30	45
Avg. of 2nd 7 yrs.	20.7	17·4	18·4	18·5	18·62	8	25	40		28	31	46
Avg. of 14 Yrs.	21·7	18·2	19·2	19·9	19·56	10	22	43		27	30	45

Year	Zymotic: Total in Year.	Rate per 1000	Total pr. Qr. 1st.	2nd.	3rd.	4th.	Pulmonary: Total in Year.	Total pr. Qr. 1st.	2nd.	3rd.	4th.	Mean Temperature. Quarterly. 1st.	2nd.	3rd.	4th.	Year	Rainfall. Quarterly. 1st.	2nd.	3rd.	4th.	Year.
												°	°	°	°	°	Inches.	Inches.	Inches.	Inches.	Inches.
1865	187	4·56	16	25	56	90						36·5	55·0	61·9	44·9	49·6	6·32	5·56	7·29	11·34	30·51
1866	161	3·6	71	36	30	21						40·7	53·9	60·0	45·1	49·9	11·70	7·26	8·71	4·71	32·38
1867	91	1·9	23	19	21	25	153	62	30	17	44	38·2	55·1	60·0	41·7	49·1	6·94	5·12	8·86	4·12	25·04
1868	210	4·3	41	69	77	30	141	43	33	22	43	41·4	57·7	64·1	44·4	51·8	6·61	3·03	6·92	8·02	24·58
1869	159	3·6	30	25	71	61	165	50	36	27	52	41·7	53·5	61·7	44·2	50·3	6·89	5·70	5·22	7·57	25·38
1870	216	4·0	48	38	77	53	176	69	45	18	44	38·3	55·3	61·6	42·2	49·5	4·99	1·48	6·64	9.16	22·27
1871	224	4·0	76	62	66	26	163	56	43	20	44	41·0	52·9	61·8	42·6	49·6	5·56	6·91	8·70	3·37	24·54
1872	166	2·9	45	41	58	22	137	38	36	20	43	44·7	53·9	62·0	46·3	51·8	8·74	6·24	7·16	13·13	35·27
1873	79	1·3	24	9	32	14	145	47	44	17	37	40·6	53·4	60·9	44·8	49·7	7·32	5·25	7·10	6·04	25·71
1874	152	2·5	29	56	42	25	179	56	35	25	63	42·2	51·3	62·0	42·8	50·3	3·53	5·27	6·08	9·22	24·10
1875	231	3·6	25	55	58	93	205	94	38	23	52	40·8	51·6	61·6	44·5	50·4	5·18	4·95	8·30	8·44	26·87
1876	227	3·5	61	36	79	51	162	52	42	24	44	40·7	53·5	62·6	47·8	51·2	5·66	3·59	6·16	11·41	26·82
1877	178	2·7	57	37	50	34	181	65	58	23	37	43·1	53·8	59·9	45·5	50·6	9·38	7·35	6·93	8·52	32·18
1878	196	2·9	34	23	92	47	195	69	31	28	67	42·2	56·4	61·9	42·1	50·7	3·73	10·70	7·02	7·26	28·71
1879			33	33				91	61			38·0	51·4				6·56	10·08			
Avg. of 1st 7 Yrs.	183	3·6	44	39	56	44	160	56	37	21	45	39·7	54·8	61·6	43·6	49·97	7·00	5.24	7·48	6·90	26·61
Avg. of 2nd 7 yrs.	176	2·8	39	37	59	41	172	60	41	23	49	42·0	54·3	61·6	44·8	50·67	6·22	6·19	6·96	9·15	28·52
Avg. of 14 Yrs.	179	3·02	38	41	57	42	166	58	39	22	47	40·8	54·5	61·6	44·2	50·32	6·61	5·71	7·22	8·02	27·56

To face page 220.]

G. Corden.

cut off from the sewers, and the main sewer was in a very choked condition, I fully believe it was to some extent answerable for the second outbreak of fever that year, which took place about a fortnight afterwards.

I am aware that great efforts have been made by the local authorities since then to cut off all direct communications between the sewers and the interior of houses, and also to divert the surface and storm-water from the sewers; but still much must remain to be done, and until done, and that thoroughly, if the abnormal conditions of the rainfall as of late years exhibited are to continue, so zymotic diseases may rear their ugly heads amongst us.

At the same time there is much to be thankful for in the fact, that zymotic diseases are occasional visitors only, and the general death-rate of the district is very much below that of large towns generally, and frequently below the average of all England.

GEO. CORDEN.

DR. BLACK said that very excellent results had been obtained by the medical officers of health in Scotland from charting the rise or fall of the death-rate from various diseases.

DR. A. CARPENTER said that there was much in the paper which his friend Mr. Corden had read which was important and interesting, especially as pointing out the connection of heat and cold with mortality, and also the connection between heavy and sudden rainfall and the rise of enteric fever. It would be a means of enlightening some upon the evils which undoutedly arose from defective sewers and an impure subsoil, and pointed to a necessity for preventing increase of impurity in the latter. The paper represented an enormous amount of detail work which reflected great credit upon the observer, and will be found of use to the local sanitarian for all time. It would help to prove the point which he (Dr. Carpenter) had always maintained, that enthetic disease was caused by impure air from the subsoil finding its way into houses at night, as well as by means of impure water-supply. It was a reason for all good Sanitarians considering the nature of the material upon which houses were built, and taking measures to prevent the intrusion of foul air from foundations as well as by sewer channels.

As a contribution towards the discussion on Mr. G. Corden's paper on the "Influence of Weather on Disease," Mr. Edward Mawley, F.M.S., exhibited a chart which he explained in a short paper, read by Mr. JAMES CHISHOLM, entitled "Eleven Months of Cold Weather" (November 1878—September 1879), of which the following is an abstract:—

The weather of the past eleven months had been throughout of so exceptional a character that he thought a diagram illustrating the most remarkable features of it—its low temperatures and heavy rainfall—and at the same time indicating its influence upon the health of the inhabitants of so large a city as London, could not but prove of interest to those assembled for the purpose of discussing Meteorology in connection with Sanitary Science.

Temperature of the air at Greenwich.—The mean temperature of the whole period was 3½ degrees in defect of the average of the previous 20 years. The coldest month (January) being 6°·8 below the mean, and the least unseasonably cold one, March (0°·4) below it.

Mortality in London.—The eleven months were on the whole healthy, the average number of deaths per week being 18 less than is usual. During the first seven months, or in the winter and spring, the deaths exceeded the average of the previous 10 years by 79 per week. Whereas in the remaining four months, or in the summer and early autumn, they fell short of it by as many as 195 per week. July was the healthiest month, the total number of deaths being 1730 less than the average; while March proved the most unhealthy, 1420 persons dying during the course of it in excess of the average number. It should, however, be explained that the latter, although this year the most seasonable of any in temperature, was a month of changable weather, and followed the longest cold period that we have experienced for many years.

Owing to the absence of epidemics of a severe character, the foregoing particulars might be taken as fairly indicating the direct influence of low temperatures, long continued, upon the public health both in winter and also in summer.

Rainfall at Addiscombe, Croydon.—The total fall in Croydon in the eleven months was nearly 9¼ inches in excess of the mean amount for the previous 19 years, August being the wettest (4·613 inches), and March the driest (0·559 inches) month. So that the month last named was at once the most seasonable in temperature, the driest and the most unhealthy. Mr. Mawley doubted whether the influence of rain upon health could be traced in the same clear way as that of heat or cold, but considered that the beneficial effects of a heavy rainfall, like that of the last few months, must in large towns, where even the air itself was rendered all the more wholesome by an occasional washing, undoubtedly have been very great.

Diseases of the respiratory organs and zymotic diseases.—The number of deaths in London from diseases of the respiratory organs was in nearly every week of the period under consideration in excess of the average. While on the other hand, with as few exceptions, diseases of the zymotic class had proved much less fatal than usual. The greatest number of deaths from chest complaints occurred in March, and exceeded the average of the previous ten years by over 1000; whereas between the middle of July and the middle of August there were about 1200 less deaths from fevers, diarrhœa, &c., than is usually the case.

Mr. Mawley, in conclusion, expressed the opinion that our Sanitary reformers migh justly claim some credit for the uniformly satisfactory position of that curve on the chart which represented the number of deaths from zymotic diseases, as this curve might be taken as affording a tolerably correct indication of the present Sanitary condition of our giant metropolis.

In answer to Dr. Black, who said that the charts which I exhibited were not referred to in the paper, and who went on to enlarge upon the very excellent result obtained from a systematic charting of the rise or fall of the death-rate from various diseases, as followed by Medical Officers of Health in Scotland, I said that the charts exhibited were, with one exception, meteorological only, and shown for the purpose of contrasting the temperature and rainfall of the years 1870 and 1879. The exception was the chart showing the means and totals for each month for fourteen years, on which was marked for each quarter the death-rate from zymotic diseases, and each point was connected by a blue line or trace, by which the eye could take in very readily the variations from the mean.

Conditions of the Water Supply of Croydon, in relation to its Rainfall and Geology; with Suggestions for its Sanitary and Profitable Improvement.

In the autumn of 1875, Croydon was visited with a very violent epidemic in the form of enteric fever of the typhoid class. As this form of fever is such as can be very generally attributed to defective Sanitary conditions, attention was vigilantly directed to the surrounding Sanitary conditions by the Local Board of Health; but as the disease continued for a considerable period with fatal effects, it was thought necessary to call the attention of the Government to the matter, and a Sanitary Inspector was sent down from Whitehall, who sat for some time in Croydon to hear evidence and to examine the general Sanitary conditions which might be thought to have encouraged the disease. This ended, I believe, in certain recommendations by the inspector, which were duly carried out by the Local Board of Health.

At the period of this epidemic it became the general public opinion in this district that the spread of the epidemic was due to one cause only, contagion conveyed in some manner through the water supply. This was at the time thought to be very clear, as it was confined, or very nearly so, to the area supplied by the Croydon Waterworks, which covers only a part of the entire district. In this district, amongst others that were supplied, there was one very striking instance in the immediate neighbourhood where I reside. On one side of the Selhurst Road the epidemic prevailed, that is the side that was supplied with the Croydon water; whereas on the other side there were no cases, where the houses were supplied by the Lambeth Waterworks.

Further, Gilhurst Road being a new road, the Sanitary conditions were equal or perhaps a little better on the side supplied with the

Croydon water, as the houses were newer and better built, on plans approved by the Board of Health; whereas many of the other houses on the opposite side were built before the existence of this Board. Further, generally there were no cases in any direction *beyond* the Croydon water supply. As soon as the cause was discovered, housekeepers took the precaution to boil the water used for drinking purposes, and the epidemic disappeared.

At the time, I took some pains to inquire into the general conditions of the water supply, entered into communication with the inspector, and pointed out some Sanitary arrangements that I thought necessary. I am not aware whether these were or were not carried out, but I know that some of these conditions remain. I have since thought the matter seriously over, and I have come to the conclusion that the meeting of the Sanitary Congress in Croydon would be a proper time to bring my ideas of the subject forward, as I feel quite sure that this is the best means of testing their value. I think that it is also in another way a proper time. There is now no epidemic in Croydon, and persons that might have felt excitement at the time, will look on with that dispassionate coolness which is necessary for all scientific investigations, so as to consider the matter in its simple health-bearing conditions for future periods only. Otherwise there was a kind of *stain*, if I may so express it, inflicted upon the purity of the Croydon water at the time of the epidemic, which has not been entirely removed by any important change of circumstances; and I feel that if the subject is now fairly ventilated, that stain may be removed. I have lately spoken of this matter to a gentleman who is present, who tells me that he still has all water first boiled before it is drunk by his family; and other like cases have been given to me; so that if this suspicion exists, it is at least not pleasant in a Sanitary point, and would be better removed.

I will now, if you please, point out the general conditions of the water supply, and consider it in a Sanitary sense.

In the first place, the water supply of Croydon is pumped by machinery from what is termed in the neighbourhood an Artesian well. But the conditions of this well, or rather group of wells, as there are more than one, is so different from the general conditions of Artesian wells, that I doubt exceedingly whether it would be accredited as such by scientific men.

This matter I will now take in detail.

1. POSITION OF THE WELLS IN RELATION TO RAINFALL AND DRAINAGE.

In this matter I must ask you for the time to neglect all conditions of the soil (which we will hereafter consider), and take the conditions of the surface relatively to drainage by levels only. This is in a certain degree necessary. A great extent of surface is covered by roads, paths, buildings and paved spaces, so as to permit surface drainage only. Further, soils which are in degree

permeable to water, and permit the ordinary rains to be entirely absorbed, will in case of storms or in very heavy rains drain off a very large portion of the water by surface drainage, only to the lowest contiguous levels. For the general condition of surface levels, as regards the position of the Croydon Waterworks, I have here one of the six-inch Ordnance maps of the Croydon district. By following the bench mark at the position of the waterworks in Surrey Street, we find one near with a reading 162·9; this point would be then approximately 163 feet above mean water at the sea coast. I have in the diagram taken this for our starting-point, and have coloured this lowest point of the surrounding district dark blue, and have extended this colour over all the district that lies as low as or lower than this, according to the bench marks. I have made the next level somewhat lighter, to include all surfaces of 180 feet above datum line, that is 17 feet above the level of the waterworks. The next 200 feet, or 37 feet above. The next 250 feet, and the next 300 feet and upwards; shading this off where it goes to 400 feet to white, so that the diagram fairly represents by jumps of 17 feet to 50 feet the natural surface drainage of the district. I have shown by very dark blue the River Wandle, which collects the surrounding drainage as a considerable stream, and conveys it to the Thames.

By this diagram it appears that the position of the Croydon Waterworks is near the bottom of a large valley extending over an area of about perhaps six or seven square miles, of which this part of the neighbourhood forms the natural drainage outlet. This position has possibly been in an old water way draining a much greater area, of which the sharp declivity represented by Crown Hill, taking the direction north and south of the High Street, has been one of the banks. The corresponding opposite bank passing at the foot of the range of hills towards the south, of which Park Hill, the Waldrons, and Duppas Hill form a part. This may be clearly seen by the lines of shading. The conditions of the above as regards the rainfall of the higher immediate districts would be that the surface drainage would be for a large part constantly directed towards the point occupied by the waterworks; so that what danger might be derived from solution of effete surface matter in such a system would depend in a large degree upon what means were taken to avoid its intrusion into the water-supply system. But under any conditions, it would be brought into such contiguity by its natural flow, as to be dangerous in a Sanitary sense. To this matter I will return after briefly noticing the geological conditions.

2. POSITION OF THE WATER IN RELATION TO THE GEOLOGY OF THE DISTRICT.

The town of Croydon and the surrounding district is situated mostly upon the outcrop of the series of beds known as the lower tertiaries of the London basin. The outcrop at Croydon is at a great angle to the lines of stratification, as we find the whole series of the lower tertiaries consisting of Thanet sands, Woolwich and

Reading beds, and the Oldhaven beds, brought to the surface in the small space of a mile north and south; as we find at Addiscombe a broad area of London clay, and at South Croydon, Coombe Cliff, and the district which lies north-east of it, the chalk or upper cretaceous. Now, this series of beds are all of porous structure—in fact, water-bearing beds, and if we sink to any depth through these surface beds, as soon as we find a retentive soil, even as retentive as that of the chalk, we may expect to obtain a fair water supply from the surface drainage alone.

That this has been a course of ancient drainage, we have direct evidence in the very shallow representatives of the lower tertiary series in the immediate position of the wells. In the lower tertiaries particularly the large development of the Oldhaven series which we find in the adjacent Shirley and Addington hills, of 100 ft. or so, and Woolwich and Reading beds, which are also fairly represented in the district, and the Thanet sands also, which together, at the lowest estimate, must at some time have formed a stratum 200 ft. to 400 ft. higher than the present level: these are denuded and washed away until they are represented in coarse gravels only by about 10 ft. above the chalk. This is seen in the section of the well which I have drawn from particulars given me by Dr. Buchanan in a letter, December, 1875.

At a later period the upper tertiaries have cut through the London clay and the older tertiary series, and have left a very thin channel of the valley gravel (in which we commonly find the remains of the elephant and mastodon elsewhere) nearly north and south over the same area, but at right angles to it, as is shown by the red space marked on the map; so that under the later tertiary period there was still an area of drainage, and the River Wandle, formed originally possibly on a cretaceous fault, has existed as a river throughout all the period that dry land has prevailed in the district since the chalk period. Under these conditions, Croydon would be naturally a district favourable for easy and copious water supply; at the same time, also, especially under the influence of surface drainage, from the direction of ancient water-ways.

I have coloured a map which gives the geology of this district as nearly as I could from data to my hand. It will be only so far in error that I cannot exactly estimate the extent of the separate beds of the lower tertiaries; but as they are entirely of one porous structure, it will not materially affect the subject of this paper.

I have also constructed a section which will extend from the clay to the chalk. I have in this section represented the strata of regular outline, which would be naturally produced by a district of even flexure of upheaval to the south of Croydon. These would be the general indicated conditions, but there occurs a fault in the general series of a band of blue clay in the cretaceous series, which I have marked by a black line in the section of the well, which indicates that the chalk is not as originally deposited. We also find that at ten feet down the one side of the section, for seven feet chalk, and the opposite side gravel. This either indicates an old cliff, whose angle would most probably extend much further, or more probably

a fault, which makes altogether, with the general surface outline, one suspect that the fault is continuous, at about a line in which the waterworks forms a point in the direction of the older tertiary valley.

The general influence of such a fault would be to create a special line of surface drainage, which would be prejudicial to the certainty of obtaining pure water at this point free from surface drainage.

SUMMARY OF THIS CONDITION.

To bring this matter generally under consideration, we find that by natural inclination of the surrounding land, particularly to the north-east and south, we have a fall in the district towards the position of the wells, and that naturally the porous strata above the chalk would, in case of considerable rainfall, saturate this strata. As the strata above would also contain the drains of the district, and every species of refuse general to the surface soil of a populous neighbourhood—as we know, when our dog or cat dies, it is buried in the garden. Further, we have not always possessed the important advantage of a Local Board of Health; so the system of drainage that we now criticize was built upon a system in old Croydon which dates earlier than the celebrated invention of Drummond, who gave us the means of keeping our inland towns much more wholesome by the pollution of our streams and water courses.

Now, such a state of surface affairs in a district of a deep sinking in the ground for potable water, does not appear to be extremely wholesome. It may be argued that one well is bricked up, and that another is lined with iron casings; but as hydraulic pressures are rather difficult things to manage, even when all parts are visible, it would be clear to many who have had dealings with this subject that it would be a great difficulty to keep an area pure surrounded with such influences.

Brick and concrete are porous materials, and iron is subject to decay by perforation in small holes. Further, it is difficult to join any large masses of metal, and impossible to test if the joints are secure when joined. So that if there is an imperfect joint under hydraulic pressure at A in the diagram, there is the greatest possible probability that the water at A would reach B.

POSSIBLE SANITARY INFLUENCE OF SUCH CONDITIONS.

I do not profess in this matter to look at things very squeamishly. I clearly understand that I am myself a chemical compound endowed with organic functions. I look also on water as another chemical compound necessary for my existence; and so long as this does not possess matters injurious to my system, I look at it chemically, and do not particularly care for its source. For instance, I have found the Lambeth water with which I am supplied sufficiently pure not to have injured me. Sometimes I have looked at a depth of it in my bath, and from the extremely yellow tone, as also from the doubtful sediment in the cistern that supplies the bath, I could wish it purer. I know also that by the aforesaid invention of the celebrated Drummond, that there is a perfect circulation by means of the great vital source of the metropolis—the Thames; that a part of the same water that flows from my house-drains will be again supplied to me after it is passed through the great vein of our local terrestrial system, and becomes again the arterial water for our existence, through the complicated agencies of the Lambeth pumping-engines, the sand filter, exposure to air in the reservoirs—which resembles, I presume, the exposure of the animal blood to the air in the lungs—and the influence of organic life in the reservoir, together with the close area of wholesome iron pipes, which will deoxydize any organic acidulous ferment; so that I can well imagine that any injurious matter that possessed an organic constitution would have decayed and become innocuous to my system before the water reached me. On the other hand, I should somewhat fear the most pellucid water taken directly from the earth where the deleterious influence of surface drainage might intrude itself every wet day, even sparingly, but to be immediately taken into my system without the preparation of any circulating system of purging agencies whatever.

What may be the agency by which epidemics spread I do not know. We have in this matter some very striking cases, which lead to the extreme probability that these diseases are organic. This is apparently the case with diptheria; it is thought to be so with cholera, where *torulæ*, not unlike the yeast ferment, have been found to be present in many cases in the stomach and fæces. In these cases, from the nature of fungoid growth or ferments, as they are termed, I do not think it probable that such forms of life are propagated in water; or even probable that such organic life could be preserved for a long time in this medium. But in a surface soil surrounded by the habitations of man and animals, there will naturally be those decaying matters which may form food for its propagation; and, if there is also surface drainage, the germ of reproduction will be washed away, and will probably retain its low character of life for a certain short period, until it is carried to a suitable soil for its propagation, which may be the human body, or other, according to the nature or constitution of the germ; for it is quite certain that germs that can live in one system will not live in another; in the same way that we find blights affect one species of vegetable life and not another, as we see in a very familiar instance: a cherry-tree will be affected by a blight, which will in no way affect a plum-tree. I offer this very brief sketch, and I must leave all details to our more competent medical men, and proceed at once to

SUGGESTIONS FOR THE SANITARY IMPROVEMENT OF OUR WATER SUPPLY.

Here we have at once, by reference to the mode in which the filthy sewage and chemical contamination of tanneries and other manufactories slushed backwards and forwards by the tides in the Thames, becomes, if not perfectly wholesome, at least not seriously injurious water. And if we followed the system by which it is purified very roughly, we could expect no deleterious effects from the small amount of injurious matter that could possibly enter our wells. But this would be really superfluous. It is quite clear to my mind that by simple exposure in a reservoir for a few days, the prevalence of organic life in the reservoir, of a type not injurious to the human system, vegetable and animal, would speedily clear it of any germs it might contain. Such species alone, as the abundant wheel animalcule which apparently consume every organic substance small enough to enter their system, would be nearly sufficient. By further refinement we should only need a second reservoir for immediate supply, with an ordinary trenched sand-bank filter, which would last for a great number of years, with our visibly pure water.

ECONOMY OF THE SYSTEM AND VALUE TO THE NEIGHBOURHOOD.

I will now point out the possible position and economy of such a system as that I propose.

By the present system water is pumped directly from the wells to supply the houses, consequently the supply is required at certain hours of the day abundantly, and at other times naturally a very small quantity would be used. For instance, in dry weather a large quantity of water is required to water roads and gardens, whereas in wet weather much less is required. It is true there is one small reservoir; but this is at such a great height, about 200 ft. above the pumps, that pumping to such a height would be entirely waste of power for the supply of the lower districts, and besides this reservoir is too small to be useful. Now every one who is connected with steam machinery knows that any intermittent use is very wasteful from the loss of heat by letting down and bringing up fires. Therefore the same engine with sufficient reservoir space would probably raise more than double the amount of water at the same expenditure, if kept in constant action night and day. So that for the absolute quantity raised, there is no doubt that it would be much more economical to keep the engines, or part of them, at constant full work, or as nearly so as possible.

In the next place, there is a large densely populated district, that in which I reside, of houses supplied at a very high rate by the Lambeth Water Company. The high price is possibly necessary as the expense of purifying the Thames water is very great, and the distance, ten miles or so, to be conveyed in pipes is very expensive. I pay for my house, rated at £45 per annum, a water-rate of £5 per annum; this is, I believe, at about three times the rate that Croydon water is supplied. There are in my immediate district—say, 1000 houses, supplied by the Lambeth Waterworks at an average of £3 per house; this would represent a gross income of £3000, which capitalized would represent, at 5 per cent., £60,000, or more than sufficient to purchase land and construct the necessary reservoirs and pay all outstanding compensations to the Lambeth Waterworks, who are now, by the growth of neighbourhoods in Surrey, experiencing more and more difficulty in providing a necessary supply. And the same changes could render the water supply wholesome for the whole district.

For this improvement I suggest Croydon is in every way adapted naturally without serious expense.

In the north, through the district of Addiscombe and part of Selhurst, there is abundance of land in the London clay, the most economic of all materials for the construction of reservoirs. Besides which, should in this area more water be required by the growth of the neighbourhood, this is the proper position to sink wells or bore, as the retentive surface-soil will not permit surface-drainage through this capping of clay. Therefore perfectly innocuous water could be drawn from the lower tertiaries direct, which I have no doubt, from the extent exposed of the Oldhaven beds of Shirley and the surrounding district, would give a large supply. But should more pure or Artesian water be desired, this district is so nearly on the border of the London clay deposits, that the green sands could be reached at much less depth than at positions deeper in the London basin in its northward extension, and the purest of all waters be obtained.

WM. F. STANLEY, F.M.S.

DR. A. CARPENTER said he had listened to Mr. Stanley's paper with some degree of interest, and would, with the President's permission, make a few remarks upon the points put forth by the reader. Mr. Stanley reminded him (Dr. C.) very much of Balaam the son of Beor, who, when called upon to curse the children of Israel, ended by blessing them entirely. Mr. Stanley makes grave charges against the Croydon Board of Health for distributing water from a dangerous source of supply, but asks them to let him have a share of it at Norwood. He is evidently not afraid of the possibility of impurity entering in at the fault which Mr. Stanley thinks to be present in the chalk at the point at which the well is sunk. Dr. C. would, however, point out that the fault, if it exists, is only a few feet from the surface, whilst the well itself is at least 175 feet deep; a fault of the character indicated could not therefore affect a well which is completely protected by iron cylinders to the very bottom of the bore hole; and, indeed, Mr. Stanley indicates his disbelief in his own theory, for he asks the Local Board to let him have the water, as being far superior to the supply which he (Mr. S.) obtains at present from the Lambeth Water Company. So much for the chance of infection from surface-water by the fault to which Mr. Stanley draws attention. Mr. Stanley says that the epidemic of 1875 was due to one cause only. He (Dr. Carpenter) demurred to this; the cause in the first place was typhoid excreta retained in defective sewers; the fact was known and pointed out at the time when it was proposed to give an intermittent supply of water to the town in the day-time. He (Dr. C.) at once said, "If you do, you will have 1000 cases of fever, because the water supply itself will become generally contaminated." He was laughed at by some of the members of the Board, and denounced in the local press; the intermittent supply was given, and 1260 cases of fever was the result. Of these cases many arose in consequence of water contamination derived from defective pipes and water-closets in immediate connection with empty sewers; but a large part of these were caused also by exhalations from the very defective sewers which existed in all parts of the town. Indeed, it is probable that if the latter had not existed the contaminated water would not have produced anything like the fatal results which followed. He held that it was fully proved that in a majority, if not in all the cases, defective sewers existed, and the air of the houses in which the victims resided was fouled by sewer air before the typhoid germs were distributed in the water supply. I feel quite certain that the water supply, as derived from the well, was pure at its source, but that it became contaminated in the process of distribution, and I make this statement because the water was proved to be fouled at one time and at one place, when it was proved to be pure in another at the same time. Nothing could be more convincing as to this fact than the evidence obtained at the Friends' School in Park Lane. The water, as supplied to the boys, smelt as it came from the tap after an intermittent supply had been obtained. It supplied the boys' bath, then filled their cistern, and, after that the girls got a quantity. The boys had complained of the water. *They had fever.* The contaminated water was washed out of the pipes, and the girls got a pure supply, and they did not have fever. He knew of several similar instances which convinced him at the time that the contamination arose after the water left the bottom of the well. Mr. Stanley might rest assured that no surface water, as such, found its way into the well at all, and that no water was supplied to the inhabitants which did not go through a very solid and definite portion of the chalk formation. There was an idea among some half-informed people that chemical analyses could not detect the presence of mischief in water. He, however, contended that no purer supply existed than that obtained from the Croydon well, and so long as chemical analyses such as those afforded by Professor Wanklyn, were to be obtained, no one need fear to use the Croydon water, and that it was not necessary to boil it before using it. It is true that boiling diminished the hardness, but it is in the hardness that its safety from typhoid germs depends. So long as that hardness is under twenty degrees, so long is the water not supersaturated with lime, and until you have a carbonic acid atmosphere in the water, you will never get a multiplication of typhoid germs, because it is by aid of free carbonic dioxide that typhoid, or any other of that class of germ, can increase and multiply. If they cannot multiply they cannot continue to exist, and mischief must abort. So long, therefore, as carbonic dioxide is fixed by the lime and the hardness is not in excess we never need fear the presence of such mischievous germs in our water supply. I must, however, counsel the Local Board to be on their guard against the time when the population will overtake their power of supply. They ought to prepare for this, and I advise that frequent analyses of the water be made, and when that analysis shows a perceptible amount of albuminoid and free ammonia, with an increase in the chlorine, it will be time for them to think of changing their source of supply; but until then I strongly advise them to let well alone. I am satisfied that chemistry will be able to direct them most fully, and they ought to consult the chemist more frequently than they do. But for a very long time to come, indeed so long as the supply continues to be only half that at which it is fixed by Mr. Lucas, we need be under no serious apprehension of mischief arising in the manner which has insisted upon by others as well as Mr. Stanley. If ten million gallons per day are available, and we take less than three millions, we are quite safe.

Mr. W. Barns Kinsey said, "I agree with Dr. Carpenter that periodical analyses of well water are necessary, particularly in certain formations, and I can endorse Mr. Stanley's remarks as to the possibility of drawing down surface water at the back of the well lining, and so contaminating the well if the bore-hole is pumped too hard. I have known this to happen in several instances."

Mr. Baldock would not dispute Mr. Stanley's geology, because the geology of Croydon was pretty well known and understood; but he could not allow the statement, that the wells from which the Croydon water was obtained were in any way connected with a recent outbreak of typhoid fever, to go unchallenged. Years ago the Bourne was charged with spreading death and destruction, when the true nature of that extraordinary flow of water was neither known nor understood; no one, however, would now think of attributing to it any such absurd fatality; so, too, the Croydon wells had been blamed, and most unjustly so, with being the cause of typhoid epidemics; but as with the Bourne, so with the wells, the time would come when the error would be discovered, and the wells acquitted. True it was that the *water* had been the innocent agent in spreading the fever, *in course of its distribution through the mains*, but the *real cause* was to be found in the disgraceful sewer system which then, and to a great extent now, underlies some parts, especially the older parts, of the town of Croydon, no better proof of which could be found than in the fact, that once started the fever spread rapidly, bad smells and tastes being observed when the water was drawn from the taps, indicating clearly the connection between the sewers and the water-pipes, *no such taste or smell ever being observable at the wells*, the water from which had repeatedly been analyzed by Dr. Odling, Dr. Frankland, and Prof. Wanklyn, and declared to be unequalled for purity; it was therefore a gross libel on the Croydon water to blame it for what was really caused by the sewers, which were badly laid, broken, and uneven, thereby becoming sewers of deposit, and the source of all abominations. When these sewers were put in order, and *all connection severed* between water-pipes and sewers, drains, and closets, and when, moreover, the supply of water was, as it had recently been made, constant and not ever intermittent, then no more would be heard of the Croydon water propagating fever. As to surface water finding its way into the wells and contaminating the water so as to produce fever, Mr. Baldock considered that this statement had only been put forward to draw attention off from the sewers, and had no foundation in fact; at any rate as now constructed, all entrance of surface water was, he considered, an absolute impossibility. The question of an *additional* source of water to meet a great increased demand, might arise some day, and then the question might be considered whether that source should be remote from the present one, but for the present, if far less than one-tithe of the money which had been so absurdly talked about for removing the whole of the present waterworks' machinery (to where?), were spent in perfecting the sewer system of Croydon, a great and undoubted Sanitary result would accrue to the town.

Mr. Hill, Mr. Cowper, Professor Wanklyn, and Mr. Lucas also took part in the discussion. The President closed the discussion by stating he agreed with Dr. Carpenter, that more storage power should be obtained by the Croydon Local Board of Health.

Mr. Stanley, in reply to Dr. Carpenter and Mr. Baldock, said, "I cannot understand the Doctor's argument that water can come from the distant parts surrounding Croydon when the surface soil up to the wells is indisputably equally porous to the distant parts. Further, for the value of chemical analysis, I do not think that disease germs, which are invisibly small, and in such minute quantities, would be possible of detection by any chemical analysis—at least, they have never been so detected at present. With regard to sewage entering the supply pipes where the hydrostatic pressure was opposite, and not entering the well where the hydrostatic pressure of surface drainage would be direct, certainly does appear to me a most remarkable argument."

Dr. Carpenter pointed out that it had not been contended that the sewage entered the pipes when the hydrostatic pressure was *opposite*, but that it took place when the pressure was *taken off* in consequence of the supply being made *intermittent* instead of *constant*. He quite agreed with Mr. Stanley that there was little chance of sewage entering the pipes when the supply was constant, but it was just because it had not been constant that the disaster had occurred.