MICROSCOPIC EXAMINATIONS OF AIR.

BY

D. DOUGLAS CUNNINGHAM, M.B.,

SURGEON H. M. INDIAN MEDICAL SERVICE,

[ON SPECIAL DUTY,]

ATTACHED TO SANITARY COMMISSIONER WITH GOVERNMENT OF INDIA.

MICROSCOPIC EXAMINATIONS OF AIR.

BY

D. DOUGLAS CUNNINGHAM, M.B.,

SURGEON H. M. INDIAN MEDICAL SERVICE,

[ON SPECIAL DUTY,]

ATTACHED TO SANITARY COMMISSIONER WITH GOVERNMENT OF INDIA.

CALCUTTA:
PRINTED BY THE SUPERINTENDENT OF GOVERNMENT PRINTING,
8, HASTINGS STREET.

CONTENTS.

ILLUSTRATIONS.

MICROSCOPIC EXAMINATIONS OF AIR.

BY

D. DOUGLAS CUNNINGHAM, M.B.

INTRODUCTION.

Subject of Report.

THE following Report contains the results of observations on the nature of the solid bodies present in the atmosphere of Calcutta and the neighbourhood. They were mainly carried on during the course of the year 1872 and dealt in greater part with the common atmospheric air, as, before entering on the examination of the characters of special atmospheres, it was necessary to acquire a thorough knowledge of the bodies generally diffused through the air and therefore liable to occur in any locality without any special significance.

Reasons for reviewing the literature of the subject.

Similar observations have been previously recorded by numerous other authors, and before proceeding to those forming the subject of the present report, it may be well briefly to review the literature relating to them, with a view to ascertain what our knowledge of the question really amounts to. It is the more desirable to do this as no general summary of the kind has, as far as I know, ever been attempted, and the information is scattered through Scientific Journals and the transactions of learned Societies in isolated papers, many of which are, when taken separately, likely to lead to very imperfect conceptions regarding the subject as a whole. In attempting anything of this kind I am well aware that the result is likely to contain numerous omissions and other imperfections, more especially in a country such as this where there is great difficulty in obtaining access to the requisite information, but, such as it is, it may yet be of use in rendering the latter part of the Report more intelligible than it might otherwise be, and in facilitating an estimate of the value of any conclusions there stated. In the following pages a chronological order has been, as much as possible, adhered to—the first observation recorded by any author being taken as a starting point for a sketch of his after work—and where this is not so or where due prominence does not seem to have been given to any set of observations, the error is to be entirely ascribed to lack of information and not to any desire to undervalue or neglect any one's work.

SECTION I.

REVIEW OF THE LITERATURE OF ATMOSPHERIC MICROGRAPHY.

Ehrenberg's observations:

Our knowledge regarding the existence of organisms in the atmosphere may be said to have commenced in 1830, when Ehrenberg published the results of a series of experiments on the subject in Poggendorff's Annals for that year. These results were that isolated forms occurred in fresh rain-water, but that careful examination of thousands of rain-drops, snow-flakes, and dew-drops had never revealed the presence of living infusoria.[1] Between 1830 and 1847 he continued his investigations on atmospheric organisms, and in the latter year published his celebrated treatise on "Passatstaub and Blutregen." The cholera epidemic of 1848[2] was the occasion of his closer study of the elements of common dust

[1] "Übersicht, der seit 1847 fortgesetzten Untersuchungen über das von der Atmosphäre unsichtbar get ragene reiche organische Leben" p. 5.

[2] Op. cit., p. 98.

deposited from the air, and of the commencement of a series of observations, the results of which appeared in the "Monatsberichte" of the Berlin Academy for 1848, 1849, 1853, 1855, and 1858. This series included observations on the dust deposited in houses, towers, museums, libraries, hospitals filled with severe cases of cholera, and on the moss on trees in Berlin; on specimens from other parts of Germany; from hills near Zurich; from Egypt during an epidemic of cholera; from Venezuela, the Bernese Oberland, and High Alps; from Lebanon, the Altai, and the Himalaya at an elevation of 20,000 feet.

His latest conclusions regarding the results of them.

In his latest publication on the subject, he states that all these observations proved the actual existence of an atmospheric kingdom of life, and that they showed not a few forms of Polygastrica, Rotifers, Tardigrades and Auguillulæ often capable of reviviscence after years of dryness.

The forms present did not belong solely to the animal kingdom, but also included sporidia and sporangia of fungi and other cryptogamic plants. The vegetable organisms were, however, constantly less numerous than those referable to the animal kingdom.[1]

No special forms of infusoria or spores were to be found in the atmospheric dust during the epidemic of cholera in 1848.

M. Gaultier de Claubry's experiments.

Shortly after the publication of Ehrenberg's observations on rain-drops, &c., M. Gaultier de Claubry tried a series of experiments on the result of passing air from various localities into water which had been previously exposed to a high temperature.[2] The results of these observations were communicated to the Société Philomathique in 1832, and showed that the animals and vegetables found in the water varied with the localities, stables, streets, wards, &c., from which the air had been derived.

Dr. Angus Smith's observations on organic matter in the air:

Even so long ago as the year 1846, Dr. Angus Smith, to whom we owe so much information regarding the impurities of air, published, in the "Memoirs of the Chemical Society," an account of some experiments bearing more or less directly on the presence of organisms or their germs in the atmosphere.[3] He pointed out that water condensed from the breath, or into which people had breathed, contained a considerable amount of organic matter, that animalcules were developed in it after a few days, and that the current belief of the day referred the development of such organisms to atmospheric germs. He also mentioned that he had procured organic matter condensed on the windows of crowded rooms, which, on standing, formed a thick glutinous mass of closely matted confervoid threads, with various species of volvox and monads.

The same observer, whilst working for the Royal Mines Commission in 1862, examined the solid impurities contained in the air of mines due to gunpowder explosions, &c. No special apparatus was required for this, as the floating crystallized bodies were spontaneously deposited on the sides of the glass tubes employed in collecting samples of air.[4] They consisted of solid products of the combustion of gunpowder, sulphate of potash, pieces of quartz or glass, dust of the rocks subjected to blasting, and filaments of organic origin.

His method of collecting the bodies suspended in the atmosphere:

In his most recent work regarding air,[5] Dr. Smith mentions that he has tried various means for securing specimens of the solid impurities of the atmosphere, among the number, filtering it through cotton wool after Pasteur's method, and that he and Mr. Dancer found solid bodies deposited on such filters when examined by the microscope. Latterly,[6] whilst engaged in experiments on disinfection for the Royal Commission on the Cattle Plague, he began the system of collecting the solids of air by frequent agitation of large bulks of it with pure water in a bottle. This serves the same purpose as drawing the air through water by an aspirator, and is much simpler and more universally applicable than the latter procedure. On examining the specimens of water so treated with the

---

[1] Op. cit., p. 100.
[2] Comptes Rendus, Tome, XLI, p. 644.
[3] "Air and Rain," p. 390. Longmans & Co., 1872.
[4] Op. cit., p. 122.
[5] Op. cit.,
[6] Op. cit., 483.

microscope, forms are visible in them at once, but no motion can usually be detected in these for some time. He was furnished by Mr. Crookes with pieces of cotton wool through which the latter gentleman had drawn the air of places infected with cattle plague, and on washing them found that some of the films were coated with small, nearly circular, structureless bodies, whilst numerous similar bodies floated free in the fluid. On examining the liquid condensed from the air of an infected cow-shed, he found similar bodies in it, together with one somewhat resembling *Paramecium*. No motion was at first visible in them, but on a subsequent examination on the following day, there was very abundant motion, and the preparation contained euglenoid cells. He found that the great difficulty in washing the air was to secure thorough purity in the distilled water, particles of impurities appearing to be carried over with the vapour.

And manner in which it was practised.

When he wished to experiment on the air, he took a bottle containing a little pure distilled water, pumped the air out of it, and opened it in the locality to be investigated. The bottle was then well shaken, the air exhausted afresh, and the same process repeated for several times. By this means he was able to determine that the air of cow-houses and stables contained more particles than that of the street in which his laboratory is situated, that these sometimes moved, "if not at first yet after a time, even if the bottle had not been opened in the interval," and that a considerable mass of *débris* with hairs or fine fibres was present. The appearances described above were not however peculiar to infected places, but were found to characterize the air of a healthy cow-house also.

Subsequently he "tried the same plan on a larger scale" by pumping out, filling, and shaking a bottle five hundred times in the open air near his laboratory. This process naturally occupied some time, and there was a considerable variety of weather whilst it was being carried on. The liquid became clouded, and very light particles were visible to the naked eye floating in it. On microscopical examination "the scene was varied in a very high degree; there was evidently organic life." He did not himself carry out any detailed microscopical examination of the specimen, but handed it over to Mr. Dancer, the results of whose investigation of it will be found further on. In commenting on Mr. Dancer's observations,[1] Dr. Smith states that the organisms in the air appear "to rise as rapidly as vapour, and are not merely dry dust driven up by wind," that "they are found less when the rain falls, so that the rain washes them down into the earth," that the mere rise of vapour may be enough to raise them, and that they tend to deposit in quiet places even when not carried down by the dew.

Observations of Meyer, Stoop and Wedl.

According to Ehrenberg[2] it is stated in Robert Brown's botanical works (published in 1847) that Meyer and Stoop observed the occurrence of microscopic organisms in rain-water four days after it had fallen, and, in meteoric dust which fell in Vienna on the 31st January 1848, Dr. Wedl found dried infusoria resembling *Bursaria* and *Colpoda* or *Paramecium*.

Brittan and Swayne's observations regarding cholera in 1849.

During the epidemic of cholera in England in 1849, among the observations published by Dr. Swayne and Mr. Brittan regarding the presence of peculiar cholera cells, there is one by the latter gentleman demonstrating their occurrence in the atmosphere of infected places. The method which he employed was to condense the air of rooms in which cases of cholera had died,[3] and the bodies discovered are described by him and Dr. Swayne as identical with the smaller "annular bodies" of the choleraic discharges. A figure of these bodies was also published and they were stated to be absent from the air of non-infected places.[4]

Report of the Sub-committee of the College of Physicians.

The discussion regarding the nature of these bodies led to the appointment by the College of Physicians of a sub-committee "on the nature and import of microscopical bodies in relation to cholera," and, among other experiments, the

[1] "Übersicht," p. 491.
[2] "Übersicht, &c.," p. 98.
[3] Lancet, October 13th, 1849.
[4] London Medical Gazette. New Series Vol. ix, 1849, p. 530.

members, Drs. Baly and Gull, tried seven on air, by condensing vapour from it, and by examining tbe dust of cobwebs and that deposited on the glass of windows, and arrived at the conclusion that "bodies presenting the characteristic forms of the so-called cholera-fungi are not to be detected in the air of infected places."[1]

Dundas Thompson's observations in 1849:

In the same year and in connection with the same epidemic, Dr. Dundas Thomson "subjected a large quantity of external atmospheric air in an infected district to chemical investigation, with the view of condensing any vapour, or of determining solid particles which might be disseminated through the air."[2] The result was negative, but in 1854, when the Board of Health sanctioned investigations with a view to the discovery of a tangible cause for the disease, he carried out a more extended and exhaustive series of similar experiments with the co-operation of Mr. Rainey, to whom the microscopical portion of the investigation was more especially committed.

Method employed by him in 1854.

The method which he employed for the collection of the solid particles contained in the air was by drawing the latter by means of a large aspirator through Woulfe's bottles containing distilled water. The first atmosphere investigated was that of a ward in St. Thomas' Hospital filled with patients suffering from cholera, and the aspiration was continued for four days. The result was that the water was found to contain filaments of cotton and wool, hairs, fine confervoid fungi, abundance of sporules, silicious particles and other inorganic bodies, and some very active vibriones.[3]

The second experiment was tried in a ward only half-full of cases of cholera, and in this case a U tube, surrounded with ice, was interposed between the mouth of the aspirating tube and the first Woulfe's bottle. The experiment lasted for 13 days, and the water showed on its termination some epithelial scales, but a comparative absence of fungi, and not a trace of vibriones.

In the third experiment the ward was empty, although in free communication with another containing cases of cholera, and the water showed lamp-black, but an almost entire absence of fungi.

In the fourth experiment the same apparatus was applied to the external atmosphere during a period of 21 days; vegetation was long in appearing, but when once established it very rapidly increased. On microscopic examination, cotton fibres, fuliginous matter and the mycelium and sporules of fungi were discovered, but no vibriones could be detected.

The fifth, and last experiment, consisted of an examination of the atmosphere of a sewer, the mouth of the collecting tube being set within a foot of the surface of the contained fluid, and the aspiration continued for 27 days. The fluid when examined showed a much smaller quantity of mechanical matters than in the previous experiments, but contained abundant mycelium and great numbers of vibriones.

Lord Godolphin Osborne on organisms in the air of choleraic localities.

During the prevalence of this epidemic of cholera the Revd. Lord Godolphin Osborne also carried on a series of observations on the presence of organisms in the atmosphere, by exposing slips of glass, slightly moistened with glycerine to the air over cesspools, gully-holes, &c., near houses in which the disease appeared, and "caught what he termed 'aerozoa,' chiefly minute germs and spores of fungi."[4]

Mr. Jabez Hogg's observations on air and rain-water:

In the work from which the above information is derived, Mr. Hogg mentions that from 1854 he himself has been in the habit of "catching these floating atoms," that they appear to him to be found in and on everything if only closely enough looked for, and that a series of experiments on rain

[1] Lancet, November 3rd, 1849, p. 493.
[2] Appendix to "Report of the Committee for Scientific Inquiries in Relation to the Cholera Epidemic of 1854," General Board of Health Medical Council (1855), p. 121.
[3] Op. cit., p. 122.
[4] "The Microscope," Hogg, p. 295.

and distilled water, similar to those of Samuelson and Balbiani to be described further on, have quite convinced him of "the very extensive distribution of infusorial germs and their great tenacity of life."[1] In reference to rain-water, he states that specimens of protococcus pluvialis, amœbæ, and cercomonas may always be found in it in vast numbers a few hours after it is caught, and that the purest snow-water after being kept well corked for a few weeks will be found to contain amœbæ, cercomonads and other forms of animal life.

M. Baudrimont on atmospheric micrography.

In 1855 M. A. Baudrimont published an account of his experiments on the microscopical constituents of the atmosphere.[2] I regret that I have been unable to find any detailed account of his results, but his methods of experiment consisted in condensation of the atmospheric humidity, and, more frequently, in agitating the air with a small quantity of water either by means of an aspirator or by a pump. He alludes to the causes giving rise to the expectation of finding pollen and sporules in the air at certain seasons of the year, together with a throng of infusoria, but his observations did not enable him to recognise the presence of any eggs or spores.[3]

Mr. Berkeley on spores in the air.

The Rev. Mr. Berkeley in his "Introduction to Cryptogamic Botany" published in 1857, alludes to the fact of spores being wafted in the air and descending by gravity at greater or less distances, and to the existence in the dust of the trade winds of spores of fungi which must have travelled thousands of miles.

Gigot's observations on the emanations from marshes.

Two years afterwards, in 1859, M. L. Gigot published his "Recherches Expérimentales sur la Nature des Emanations maricageuses." According to Dr. Bastian the method employed by M. Gigot was "to draw the air of marshy districts through dilute sulphuric acid," with the result of filtering out a certain amount of organic *débris*.[4]

M. Quatrefages in the discussion on spontaneous generation in the French Academy.

In 1859 the dispute in the French Academy regarding spontaneous generation began, and in one of the first discussions on the subject[5] M. Quatrefages stated, that in remaining faithful to the doctrine of the non-existence of spontaneous generation, it was necessary to admit the existence of a very considerable number of germs in the atmosphere, and proceeded to give the results of his own experience in the matter. In examining the dust retained by the filters in M. Boussingault's studies of the rain of storms, he recognised the presence of spores in great numbers, together with encysted infusoria, large quantities of minute round and ovoid bodies suggestive of minute ova, and one or two minute rotifers. In following out the subject he collected dust on plates of glass in cellars and in an elevated room, and found that it presented the same features. In such specimens of dust he observed monads to begin to move four hours after their immersion in water.

Pouchet's observations on dust:

Shortly after this, M. F. Pouchet, in replying to the objections to his experiments, stated, that he had sought in vain for the ova of infusoria in the dust of his laboratory. He says—"Je n'y ai rencontré que des corpuscles extrèmement fins, des grains de pollen, des brins de laine provenant de mes habits, des fragments de tissus de végétaux, des grains de fécule et des filaments des papiers colorés employés dans mes expériences, &c., pas un œuf de Kolpode ou de Kérone."[6]

At this time he commenced an extensive series of observations on dust, the results of which were published in the same year.[7] He made more than 1,000 observations on the dust deposited in many different localities, of which he furnished a list at the close of his memoir on the subject. His results showed that the atmosphere contained a multitude of corpuscles consisting of mineral,

---

1 Op. cit., p. 414.
2 Comptes Rendus, T. xli, p. 542, 1855.
3 "The Beginnings of Life," by H. Charlton Bastian, M. D., F. R. S., London, Macmillan and Co., 1872, p. 271.
4 "The Beginnings of Life," p. 271.
5 Compt. Rendus, T. xlviii, p. 30.
6 Compt. Rendus, T. xlviii, p. 48.
7 Compt. Rendus, T. xlviii, p. 546.

vegetable and animal *débris*, in quantity proportional to the amount of wind. The mineral particles varied with the geology of the country. The main constituents of an animal nature found in the dust were various minute dried animals, such as helminths of the genus oxyuris and various species of vibriones, naviculæ, bacillaria and diatoms, fragments of coleopterous antennæ, lepidopterous scales, woollen fibres, hairs of rabbits and bats, plumes of feathers, fragments of the *tarsi* of insects, epithelial scales, and spiders' webs. Only twice were large ova, so-called cysts of infusoria, detected.

The vegetable dust consisted mainly of fragments of vegetable tissues, woody fibres in small numbers, fragments of cells and vessels, hairs of nettles and other plants, filaments of cotton, fragments of malvaceous pollen, pollen grains of epilobium and pines, and wheat starch. The latter was constantly present in very considerable quantities, and according to Pouchet was evidently what Quatrefages had mistaken for the ova of microzoa. In the same memoir he stated that he had drawn 100 litres of air through two c.c. of distilled water by means of an aspirator, and that at the close of eight days neither ova nor animalcules were present in it.

His apparatus for the collection of atmospheric particles:

In the following year the same experimenter published an account of his Aeroscope or " Moyen de rassembler dans un espace infiniment petit tous les corpuscles normalement invisibles contenus dans un volume d'air déterminé," and of the results obtained by its use.[1]

His instrument consisted of a glass tube hermetically closed at either extremity by a copper ferrule. The upper ferrule was fixed to the glass and was connected with a tube of copper terminating externally in a small funnel and internally—in the inside of the glass tube—in a very finely drawn point not more than ·5 m. m. in diameter. The other ferrule was removable and allowed of the introduction of a circular glass plate into the interior of the instrument, which was placed at 1 m. m. from the point of the tube connected with the upper ferrule. This plate was covered with adhesive matter, and, if necessary, the point of the tube was made to terminate in a minute perforated diaphragm, like the rose of a watering-pot, so as to secure the dispersion of the atmospheric particles over the surface of the plate. He employed the apparatus to collect the atmospheric dust both for direct microscopic examinations, and for experiments similar to those of Pasteur on the result of inoculating infusions with it, and satisfied himself that spores and ova were infinitely rare in the atmosphere, even of places in which they ought to abound, such as his own laboratory where infusoria and fungi were constantly present in abundance; and that media in which the atmospheric corpuscles were sown, were never more fertile than those which had not been subjected to any such contamination. It was only very exceptionally that he encountered mucedinous spores, and even more so that he detected any infusorial ova.[2]

His observations on the respiratory cavities of animals:

In the same year he carried out an extensive series of observations on the bodies introduced by the air into the respiratory organs of animals.[3] He found that these organs revealed modifications in the medium respired. The most remarkable point in regard to animals living in towns, houses, &c., was the enormous quantities of starch (together with particles of soot and fragments of clothing) present in the respiratory cavities. The quantity of these foreign bodies diminished with the distance from houses, until, in birds and mammals constantly inhabiting forests, they almost entirely disappeared in many cases, and were replaced by vegetable *débris*, chlorophyll granules, &c. In the respiratory organs of some human subjects which he examined, he also found various foreign bodies, among which, in one instance, were living arachnidan larvæ, and in another, fragments of glass, soot, &c. In the humerus of a fowl which he examined, he found fragments of glass, living filariæ, and two bodies resembling dried infusoria. In all his observations, numbering by hundreds, he never found a single spore or ovum of a microzoid.

[1] Compt. Rendus. T. l, p. 748.

[2] " Études Expérimentales sur la Génèse Spontanée." Annales des Sciences Naturalles Quatrième Série, T., xviii, Paris, 1862.

[3] Comptes Rendus, T. L, p. 1121.

About the same time he examined freshly fallen snow, in order to ascertain whether it contained any recognisable organisms.[1] He pointed out that the dirty appearance of thawing snow was due to the abundance of atmospheric particles collected by it whilst falling. The snow examined was collected in an elevated site in Rouen, and afforded material for several hundred microscopic preparations. It was found to contain an abundance of particles of soot and starch grains, some fragments of vegetable tissue, a few pollen grains, some filaments of wool, grains of silica and lime, and two spores of *Lycoperdon*. He also found two encysted infusoria or ova, three naviculæ, three bacillaria, and two bacteria, together with a considerable quantity of green organised matter in flakes, or isolated and in pairs of ovoid bodies.

And on the impurities of snow.

In completing this extended investigation the same author carefully analysed the air of various other localities; of the open sea; of mountains above the zone of habitation and cultivation,[2] and of the summit of Mont Blanc.[3] In such localities he found atmospheric corpuscles to be infinitely rare, and was never able to recognise any bodies which could be determined to be starch, ova of infusoria or spores of mucedines. The examination of the snow from mountains confirmed him in these conclusions.

Pasteur's results and the means by which they were obtained.

In 1860, shortly after M. Pouchet had published the results of his first experiments on the air, his great opponent Pasteur appeared in the field with a series of statements of an entirely different nature.[4] Adopting Schroeder's and Dusch's principle of atmospheric filtration, but substituting gun-cotton for common cotton wool, he drew air through this filter by means of an aspirator. The gun-cotton was subsequently dissolved in alcohol and ether, and the deposit after being decanted into a watch-glass, repeatedly washed with distilled water and treated with liquor potassæ, was subjected to microscopic examination under a power of 180 diameters. He found that it contained variable quantities of corpuscles measuring from 0·01 to 0 15 m. m., and which in form and structure appeared to him to be organic. Starch was present only in comparatively small quantity. The organic corpuscles were unaffected by concentrated sulphuric acid, and were therefore probably the spores of mucedines. He mentions[5] that when he undertook these first experiments "diverses personnes très autorisés etaient désireuses de constater par elles-mêmes l'exactitude de mes resultats parce que me disaient elles, ayant eu l' occasion assez fréquente d' étudier des poussiéres elles n'y avaient pas vu de spores."

Pursuing these observations he came to the conclusions that a pellet of gun-cotton exposed to a current of air in the Rue d' Ulm for 24 hours in summer, after a series of fine days, filtered out several thousand organised corpuscles for every litre of air drawn through it;[6] that germs were not evenly distributed through the atmosphere; that rain diminished their numbers;[7] that still air, such as that in the cellars of the Observatory in Paris, contained few or none of them; that it was impossible for the most skilful naturalist to decide whether they were of animal or vegetable nature, but that "bodies resembling encysted infusoria were occasionally found, and also globules resembling eggs of these creatures."[8] At a later period he found pus cells in the water condensed from the air of localities in which cases of suppuration abounded, and, on examining air expelled from the hospitals during the last epidemic of cholera in Paris, discovered all kinds of spores present in it.

MM. Joly and Musset's observations.

MM. N. Joly and Charles Musset also came forward in 1860 with the result of observations on the air.[9] They affirmed that they had repeated Pasteur's experiments at Toulouse, had found his method imperfect and had arrived at conclusions similar

[1] Comptes Rendus, T. l., p. 532.
[2] Comptes Rendus, T. l. p. 1014.
[3] Comptes Rendus, T. lvii, p. 765.
[4] Comptes Rendus. T. li, p. 303, 1860.
[5] Annales des Sc. Nat, T. xvi, p. 24.
[6] Annales de Chimie et de Physique, 1862, p. 32.
[7] Comptes Rendus, T. li, p. 348.
[8] "The Beginnings of Life," p. 274.
[9] Comptes Rendus, T. l, p. 647.

to those of M. Pouchet. According to them the atmosphere in winter, and under the circumstances in which their experiments were carried on, only contains a very small number of organised bodies, one quite insufficient to account for the immense number of microscopic beings appearing in infusions. The result of their experiments was communicated to the Academy of Sciences in Toulouse in March 1860. Independently of Pouchet they were led to examine snow as an index of the organic contaminations of the air, and in it they found the same bodies as in dust; the same absence of germs or their presence in very small numbers only. They also examined natural deposits of dust with similar results and found that a mass of cotton-wool suspended at an elevation of 6 *mètres* from the soil during a period of 15 days only contained a very small quantity of organic corpuscles.

The same authors subsequently appeared prominently in the acrimonious discussion regarding the air of mountainous regions, but, as their experiments and statements bear reference to the effect of the admission of such air to infusions rather than to microscopical investigations of the bodies actually present in it itself, they need not be further alluded to here.

Information in the Reports of the Army Medical Department:

The Annual Reports of the Army Medical Department for the year 1860 and onwards contain much valuable matter regarding the particles suspended in atmospheric air, both in the form of Reports on original investigations and in Dr. Parkes' yearly summaries of the progress of Hygienic Science.

Report on the Barracks at Gravesend.

The volume for 1861 [1] contains a "Report on the ventilation of the New Barracks at Gravesend," by Drs. Hewlett, St. John Stanley and Baynes Reed. In order to discover the suspended impurities in a barrack room, 8·088 cubic feet of air was drawn through a solution of permanganate of potash by means of an aspirator. The solution was decolorized and a deposit occurred, which, on microscopic examination, was found to consist of scales of pavement epithelium, fragments of cotton fibres and shreds of wool, together with amorphous particles in large numbers.

Frank and Devergie's experiments:

In this year also Dr. Frank examined the air of the wards in Fort Pitt, by means of Pouchet's Aeroscope and in several instances detected the presence of *unequivocal* epithelial cells. In Dr. Parkes' "Review" for 1862 [2] it is mentioned that, among recent continental observations, Devergie had "examined the air in the vicinity of a patient with hospital-gangrene and detected an enormous proportion of organic matter in it," and that a good many experiments were tried regarding the air at Fort Pitt. Drawing air through water was found more convenient than the use of Pouchet's aeroscope and the amount of suspended matter thus found, even in the air of well-ventilated wards, was most remarkable. "Bits of wool, cotton, particles of hair, and epithelial cells were most common." Small cells of uncertain origin were also present, and particles of dust and starch together with other bodies of uncertain origin occurred occasionally.

Dr. F. de Chaumont's Reports.

In 1865 a "Report on the ventilation of the New Military Hospital at Hilsea," by Dr. F. de Chaumont, appeared, in which the author states that "the aeroscope showed suspended matters, portions of cloth, wool, &c., and some fragments of coal and ashes; but on the whole very little." [3]

In the volume for 1867 [4] another Report by the same observer "of an experimental investigation into the ventilation of new barracks at Chelsea" was published. The aeroscope was not employed in this instance, but 120 cubic feet of air were drawn through a freezing mixture and 4·7 c. c. of fluid condensed from it. This was found to contain epithelium in large quantity, hair and various fibres, sand, soot, crystalline substances and chloride of sodium? together with sporangia of fungi and monads in considerable quantity."

---

[1] The Statistical Sanitary and Medical Reports of the Army Medical Department for 1861, p. 382.
[2] Op. cit. 1862, p. 308.
[3] Op. cit. 1865, p. 457.
[4] Op. cit. 1867, p. 272.

Dr. Wright's observations.

The volume for 1868[1] contains an appendix entitled "Observations on the air of Barrack Room, Royal Victoria Hospital, Netley" by Dr. R. T. Wright. The observations were conducted on the nights of the 9th and 10th of July 1869 and included a microscopical examination of the solid impurities of the air. Twenty-six cubic feet of air were drawn through a little water by means of an aspirator and the suspended matter collected. It was composed of cotton fibres, starch granules, crystalline particles of dust, fragments of vegetable tissues of various sorts, pollen, amorphous molecules, detritus of epithelium, indefinite filaments and minute moving particles.

MM. Eiselt and Bechi's experiments.

Early in 1861, Dr. Eiselt of Prague published an account of his discovery of pus cells in the air of the Orphan Asylum in that city by means of Pouchet's aeroscope.[2] In the same year the results of M. E. Bechi's investigation into the air of the marshes in Tuscany appeared in the *Comptes Rendus*.[3] He examined the air of the country near the marsh of Scarlino, which is a very feverish locality. His experiments were chiefly carried on in the months from June to November, and were mainly directed to a chemical examination of the vapour deposited from the air, either as natural dew, or as the result of artificial means for securing its condensation. On some occasions only vegetable filaments were developed in these specimens of fluid after several days. They floated on the surface and were found to belong to a kind of alga. The fluid itself when quite recent showed no microscopic organisms, and the algal filaments, above alluded to, were not peculiar to it, but were found to occur in distilled water when left to itself for some time.

The Lancet's description of the dust in town-houses.

In the *Lancet* of October 19th, 1861, it is mentioned that the dust abounding in town houses in dry weather consists in great part of pulverized horse-dung and the grindings of shoe-leather, and that starch corpuscles are the most constant of its organic constituents.

Reveil and Chalvet on the air of St Louis.

In 1862 Reveil, by means of an aeroscope, showed that the air in the surgical wards in the hospital of St. Louis contained epithelial cells and filaments of lint charged with organic corpuscles,[4] and in the same year Chalvet examined the air of the same hospital, whilst being cleaned, with much the same results, finding a very large mass of organic matter mainly composed of epithelium.[5]

Dr. Jeffries Wyman on atmospheric dust.

In this year also Dr. Jeffries Wyman and Dr. Salisbury published accounts of what seem to have been the first American researches on the solid impurities of the air. The former author, whilst engaged in experiments on the subject of spontaneous generation,[6] was led to examine the dust deposited in attics, as well as floating atmospheric dust collected on glass plates coated with glycerine. He found the *débris* of animal and vegetable tissues (the latter in much greater quantity), starch-corpuscles, spores—some of which were apparently of confervoid nature—and much less frequently bodies which seemed to be ova of invertebrate animals. Both eggs and spores were of rare occurrence, compared with the dust or even with the organic constituents of it. He found no dried animalcules capable of resuscitation and no animalcules appeared until the dust had been macerated for several days, but at a later period he writes that "abundant proof has been brought forward to show that the spores or germs of infusoria exist in the air in quantities amply sufficient to account for the presence of living organisms in solutions freely exposed."[7]

Dr. Salisbury on the cause of malarial fevers:

Dr. Salisbury's observations bear reference to the causation of intermittent and remittent fevers.[8] In the year 1862 there was a great prevalence of intermittent fevers in the low marshy valleys of the Ohio and Mississipi. They appeared in the month

[1] Op. cit. 1868, p. 251.
[2] Wochenblatt Zeitschrift der K. K. Gesellschaft der Aertzte in Wien, No. 13, 1861.
[3] Comptes Rendus, T. lii, p. 852.
[4] Ann. d'Hygiène,, July 1862, p. 240, quoted by Parkes, "Practical Hygiene," Third Edition, p. 87.
[5] Revue Médicale, June 30, 1862, p. 15.
[6] American Journal of Science and Arts, second series, vol. xxxiv, p. 79, November 1862.
[7] American Journal of Science and Arts, September 1867.
[8] American Journal of Medical Sciences, April 1866, p. 51.

of May, and were very prevalent in July and August. The season was a very wet one up to the end of June, but there was no rain in July, August or September, and with the cessation of the rain the increase in the number of cases of fever occurred. Dr. Salisbury in the first place examined saliva and mucus from the mouth and *nares* of the sufferers, and detected the presence of large numbers of zoospores, animalcules, diatoms, desmids, cells and filaments of algæ, and spores of fungi. The only bodies which were of constant occurrence, and generally in great abundance, were small oblong cellules which were either isolated or grouped in masses. They had a distinct nucleus contained within a smooth cellular envelope. He decided that they were algal cellules chiefly resembling palmellæ, and found that they only occurred in malarial districts.

His method of observation:

He then proceeded to look for them in the air, his method of procedure being to suspend pieces of glass over marshy pools and swampy places. The glasses were set in the evening and removed before sun-rise next morning. Drops of water were found adhering to their under-surfaces and containing numerous cells of various kinds, but none resembling the peculiar palmelloid cellules previously alluded to. These were however constantly present in considerable numbers on the upper surfaces. His next step was to endeavour to ascertain from what source they were derived, and, after a considerable amount of fruitless search, he discovered it in a sort of greyish mould covering the recently exposed surfaces of cracks in rich prairie ground, which had been recently dried and was much broken up by the feet of cattle. On suspending glasses over places covered by this mould, he found numbers of the cellules in the fluid on their under-surfaces.

Its results.

In following out these experiments Dr. Salisbury came to the conclusions that cryptogamic spores rise chiefly during the night and fall shortly after sun-rise; that the height to which the cellules in question rose was 30 to 100 feet from the surface; that none of them were present during the day; that covering the soil to a depth of several inches with straw or quicklime prevented their rise; that a stay of 15 minutes in places in which they abounded gave rise to dryness and febrile heat of the throat coincident with their presence in the pharyngeal mucus; and that persons exposed to their inhalation, even far from their original source, under entirely different circumstances, in non-malarial districts, suffered from attacks of fever as a consequence.[1]

MM. Samuelson and Balbiani's Experiments.

MM. Samuelson and Balbiani also at this time began a series of experiments on air and investigations into the constituents of dust, in one of the earliest of which the latter observer found *Cyclidium glaucoma* in the moistened dust from a window. Mr. Samuelson communicated the results of his work both to the French Academy[2] and to the British Association in the following year. He stated that he had procured specimens of dust from Japan, Alexandria, Trieste, Tunis, Peru and Melbourne, and that, on sowing portions of them in distilled water, he always obtained a multitude of infusoria. These consisted mainly of monads, vibriones, amœbæ and cercomonads. Pure distilled water never showed any organisms so long as it was covered in such a way as to exclude dust, but when exposed for a day it was found to contain a light sediment composed of mineral and vegetable particles, embedded in a gelatinous basis formed of sessile monads which subsequently resumed life and activity and "peopled the water."[3]

In the dust from window panes when immersed in distilled water he found specimens of *Cercomonas fusiformis*, *Amœbæ*, *Vorticellæ*, *Enchelis*, *Kerona* (?) and cysts containing zoospores, together with vegetable cells in great number and variety, and on one occasion large quantities of *Protococcus pluvialis*. Vibriones and monads were of daily occurrence. His conclusions in his memoir

---

[1] In the "Journal de Médicine de Bruxelles" for April 1866, Dr. Hannon published a letter elicited by the appearance of Dr. Salisbury's observations in reference to "the cryptogamic origin of intermittent or marsh fevers." In this he stated that the facts had been long known in Belgium, that Professor Charles Morren of Liege, even so far back as 1843, had warned him of the risks of cultivating *Vaucheriæ*, *Oscillatoriæ* and *Confervæ*, and that he himself actually did suffer from fever wilst engaged in such work.

[2] Comptes Rendus, T. LVII., p. 87. "Micrographie Atmosphérique."

[3] Quart. Journal of Science, p. 484, Oct. 1870. "The Controversy on Spontaneous Generation with recent Experiments," by J. Samuelson.

to the Academy were as follows[1]:—1. "The atmosphere in all parts of the world is more or less charged with corpuscles belonging to the three kingdoms of nature, the animal, vegetable and mineral: with particles of silica, chalk, &c., with vegetable matters, fresh and in a state of decomposition, with animal and vegetable fibrils, cysts and germs of infusoria, and probably, in some more rare cases, of nematoid worms.

2. "The infusoria consist in greater part of the germs of the obscure types known at present as *Monads, Vibriones, Kolpoda*, &c., but those of *Cyclidia, Trachelians, Keronians, Vorticellæ*, &c., are likewise present.

3. "These organised bodies are present in variable quantities according to the condition of the atmosphere, more abundant when the atmosphere is dry and less so when there is much rain; they float in the entire atmosphere, and ordinarily they penetrate everywhere with it.

4. "The tenacity of life of the germs, and specially of those of the obscure forms vibrio, monas and bacterium, is much stronger than is admitted by some observers."

Observations by Mr. Samuelson regarding developments in distilled water exposed to the air:

In his paper read before the British Association of the same year, Mr. Samuelson pointed out the practical importance of examining the air of wards. In June, July and August 1870, he repeated these experiments by exposing saucers of distilled water to the air. At the conclusion of the exposure he found that the fluid contained particles of soot and silex, and minute moving germs. On keeping some of this water for some time, occasionally adding a little distilled water to make up for loss by evaporation, zoospores and other unicellular forms together with amœbæ appeared. Some saucers which had been exposed to the air for 16 days, on some of which rain had fallen, were found dried up and containing a good deal of dust. After being kept for 12 days more, this dust was heated to 480°C and 280°C, and subsequently boiled in distilled water. Some hours afterwards, the water was divided between two test-tubes, one of which was left open, while the other was plugged with cotton wool. On examining the fluid in the open tube five days afterwards, active cercomonads and "other lowly types" were found, and four days later, though the developments in the plugged tube were not so advanced or various as in the open one, they were alike in character, and active amœbæ were present in both specimens. The result of all his observations have led Mr. Samuelson to the conclusion that the most conspicuous types of organisms occurring in distilled water in saucers, exposed to the air in open situations, are amœbæ and fusiform monads; and, " that the time is not far distant when all these lowly types, now known as protozoa, will be traced in their earliest stages to the atmosphere, the dust of the road, of our parlour windows, and indeed of every place into which air and dust penetrate."

Also in the rain-water of various localities.

The same author also tried experiments on the existence of organisms or their germs in rain water. On the 4th of August 1870 he caught some rain as it fell and kept it exposed to the air in a tall champagne glass. The fluid contained numerous particles of dust, but at first showed no evidence of the presence of any living bodies; organic particles, fragments of minerals, empty sheaths, empty cell-walls and moving specks being all the objects to be detected in it. When again examined after an interval of five days numerous yeast-like cells were found in it.

On the 22nd August he again caught some falling rain in two localities in Liverpool; one in the very outskirts, the other in one of the most unhealthy of the lower parts of the town. In the former specimen, at the time it was obtained, there were a few unicellular organisms and a little soot and silex; in the latter one there were no animal or vegetable germs, but large quantities of soot and silex. On the following day the first preparation was found to be full of the unicellular bodies previously alluded to, which were now budding out into filaments; whilst in the second, at the same time, there were no germs or mycelium of any kind. On the next day the filaments in the specimen derived from the outskirts of the town, "had assumed the form of a

[1] Comptes Rendus, T. LVII, p. 89.

straggling mycelium," and "there were also swarms of minute rapidly-moving infusorial germs along with somewhat larger ciliated infusoria."[1]

M. Lemaire's observations, and experiments.

In a communication to the French Academy in the year 1863[2] M. J. Lemaire stated that his observations had demonstrated that atmospheric dust served as the aliment of infusoria, and that in certain conditions it alone allowed of the development and multiplication of these minute creatures.

In the following year he investigated the microscopic constituents of marsh-air.[3] The locality in which he carried on his experiments was Sologne, which at that time was a very malarious district. On condensing the atmospheric vapour he found it to contain microphytes and microzoa in much larger proportion than that obtained from the air of the healthy district of Romainville, 300 feet above the Seine. The bodies present were described as consisting of microphytes, bacteria and vibriones. In one case at Romainville at the time of its condensation the water contained particles of dust, filaments of various sorts, a few ovoid spores and a great many small semi-transparent bodies which were observed in other experiments also. Twenty-four hours afterwards it contained spores, bijugated cells, vibriones, bacteria and monads, and 48 hours afterwards the spores and cells had disappeared and the vibriones and bacteria had become motionless whilst the monads were still very numerous and active.

In 1867[4] and 1868[5] he studied the air of hospitals and found that the water condensed from it contained bacteria, monads and vibriones, and that the air expired from the respiratory passages contained bacteria, vibriones, fungoid cells and large numbers of round or oval diaphanous bodies. In the former year he informed the Academy that in his experiments on alcoholic and putrid fermentations, he had demonstrated that the gases given off during these processes carried up large quantities of propagula, spores and re-productive bodies of microzoa or even fully developed animalcules, and that those which he had shown to be present in the perspiratory fluid were probably diffused through the air in the same manner.[6] In the same paper he mentioned that he had found fully developed animalcules in fluid procured from the air of the Fort de l'Est, six hours after its condensation; that microphytes and microzoa were always developed in the fluid condensed from the air of dissecting rooms, of confined spaces and over marshes, that the products of respiration must often convey not the mere germs of microzoa, but even fully developed specimens of such bodies derived from decayed teeth, &c., and that the condensed vapour of breath does not putrify spontaneously, but on account of the presence of microzoa and their germs derived from the mouth, &c.

Dr. Lionel Beale on the microscopy of dust.

Dr. Lionel Beale as well as Dr. Angus Smith examined infected air during the prevalence of the cattle plague in 1866. He also obtained his specimens—consisting of cotton wool which had been exposed in glass tubes to the breath of diseased and dying animals—from Mr. Crookes. He moistened the tubes and wool with glycerine, and found that the fluid contained numbers of minute particles of various kinds, among them "undoubted sporules of fungi."[7] Dr. Beale from his long and profound experience in microscopic work is of course perfectly familiar with the ordinary constituents of atmospheric dust, and in "How to Work with the Microscope"[8] he enumerates and figures many of them, such as starch grains, fibres, fragments of feathers, hairs, insect scales, fragments of vegetable tissues, particles of sand, soot, &c. In the first of the two books quoted above, he states that the germs of fungi are almost constantly present everywhere in the atmosphere, that they are for the most part of oblong oval form and frequently exhibit a constriction, and that they belong to numerous different species and are wafted for long distances at different seasons. He also mentions that animal germs are among the familiar constituents of dust, and throws out the

[1] Quarterly Journal of Science, October 1870, p. 496.
[2] Comptes Rendus, T. LVII, p. 625, 1863.
[3] Popular Science Review, October 1864, p. 107.
[4] Recherches clinique et experimentales sur les Maladie Infectieuses, par MM. Coze et Feltz, Paris, 1872.
[5] Comptes Rendus, October 14th, 1868.
[6] "Recherches sur la nature des Miasmes fournis par le corps de l'Homme en Santé." Comptes Rendus T., LXV., 1867, p. 637.
[7] "Disease Germs, their Nature and Origin," p. 157.
[8] Fourth edition, p. 195, 196 and Plate XLIV

suggestion that the malarial poison may possibly be a degraded form of the bioplasm of lower plants and animals, incapable of returning to a healthy condition.

M. Poulet on organisms in the breath in whooping cough.

In 1867 M. V. Poulet condensed the vapour of the breath in cases of whooping cough, and found large numbers of *Bacterium termo*, of *Monas termo* and of *Bacterium bacillus* in the fluid.[1]

Mr. Dancer on the dust of flues.

Mr. Dancer of Manchester in the same year published the results of his observations on flue-dust, in which he showed that it consisted of ferruginous matters and crystallized substances, together with a large quantity of peculiar mineral spherules. As was previously mentioned in the description of Dr. Smith's experiments, it was to Mr. Dancer that the former gentleman committed the detailed microscopic examination of the results of his prolonged washing of the external air in Manchester.

He communicated the results of his investigations to the Literary and Philosophical Society of Manchester in a paper entitled "Microscopical Examination of the Solid Particles from the Air of Manchester." During the first few days of observation, few living organisms were visible, "but, as it afterwards proved, the germs of plant and animal life (probably in a dormant condition) were present." The objects ultimately detected were mainly the following, and are enumerated in the order of their prevalence. Fungoid cells were present in immense numbers, an average field of $\frac{1}{100}$th of an inch in diameter containing as many as 100 of them, which would give 250,000 in a single drop of the fluid. Mycelial filaments "similar to those of rust or mildew" on decaying vegetation were likewise abundant, which rapidly increased in quantity, and were shortly afterwards accompanied by numerous ciliated zoospores. The variety of fungi present was small, so far as could be judged from the mycelial filaments and conidial cells.

Next in frequency to the fungal elements were fragments of vegetable tissues, the greater part of which were more or less charred. They consisted of vegetable hairs, cotton fibres, and a few granules of starch and long elliptical bodies resembling the pollen of the lily.

After a few days a considerable number of infusoria made their appearance. Monads were the most abundant of these, but there were also specimens of *Paramecium aurelia*, of *Rotifers*, &c.

There was a marked absence of carbonaceous matter from the specimen, and very few animal hairs were present.

From the amount of spores or conidia in a drop of the fluid, Mr. Dancer calculates that $37\frac{1}{2}$ millions of these bodies, exclusive of other substances, were collected from 2,495 litres of "the air of Manchester"—a quantity which would be respired in about 10 hours by a man of ordinary size when actively employed.

Mr. Lund's experiments in Manchester.

In 1868 Mr. Lund of Manchester read a paper before the British Medical Association on experiments on the air of one of the surgical wards of the Manchester Royal Infirmary.[2] He employed Dr. Smith's method of procuring specimens for examination. The bottle was shaken 500 times. After 48 hours the fluid showed evidences of the presence of organic life in it, and on the 5th day it contained numerous active vorticellæ and an abundance of active monads.

Organisms in meteoric dust.

On the 24th March 1869, a fall of red meteoric dust occurred in Sicily, and Professor Silvestri of Catania, who examined it microscopically at the time of its fall, found it to contain numerous specimens of pollen, unicellular algæ apparently of the genus protococcus, spores and filaments of other algæ, and active zoospores.[3]

---

[1] Comptes Rendus, T, LXV, p. 255, 1867.
[2] Lancet, August 15, 1868.
[3] Ehrenberg. Op. cit., p. 63.

Mr. Metcalfe Johnson's "air sieve."

In a paper contained in the second volume of the Monthly Microscopical Journal[1] Mr. Metcalfe Johnson mentioned a method of collecting solid particles from the air by means of an "air sieve" and in the following year he published a short account of the apparatus.[2] It consisted of a glass plate in a small deal-box over which a stream of water trickled down, and was collected in a trough beneath. A current of air was allowed to impinge on it and the suspended particles were thus collected free from injury, the surface being at the same time more freely exposed than in Smith's method. By means of it the observer "found varying quantities of *Monas lens*, besides other air contents."

Mr. Parfitt on atmospheric sporules.

In the same year Mr. Edward Parfitt, Curator of the Devon and Exeter Institution, published a paper[3] on "spontaneous generation," in which he mentioned that in spite of having studied fungi for at least 20 years, he had never found them filling the atmosphere with sporules to the extent asserted to be the case by some authors.

Dr. Trautman on "decomposition cells."

At this time also, Dr. Trautman's observations appeared in Germany.[4] This observer condensed the vapour in the air of inhabited rooms, and found it to contain numerous small cells which he termed "decomposition cells." He found that these bodies were easily detected in the dust deposited in corners of rooms, on books, &c., and that they existed in the atmosphere "as extremely fine punctiform molecules" beginning to grow on coming in contact with water, and by a repeated process of division becoming developed into zooglœa, bacteria and vibriones. Dr. Parkes in his review of the subject states that "as to the existence of such cells in the atmosphere, there is little doubt" but that their identity with the bacteria and vibriones of fluids appears to be by no means demonstrated as yet.

Professor Tyndall's lecture on "Dust and Disease."

In the beginning of the following year general attention was attracted to the subject of solid atmospheric impurities by Professor Tyndall's brilliant lecture on "Dust and Disease" at the Royal Institution, and the result of this attention manifests itself in the scientific periodicals of the year in the form of numerous accounts of investigations on the subject.

Dr. Maddox's apparatus and experiments.

One of the first and most important of such experiments was that begun at this time by Dr. R. L. Maddox.[5] Clearly realising the fallacies inherent in methods of collecting and estimating the amount of organisms in the atmosphere such as those of Dr. Angus Smith and others, in which water is employed as the medium for their retention, he devised an instrument which, in most points, was essentially similar to the "aeroscope" used by Pouchet, but differed from it in the fact that a current of air was made to traverse it without the aid of an aspirator as employed by that observer. In Dr. Maddox's apparatus this was secured by means of a vane which, when the instrument was exposed to moving air, kept the mouth in the direction of the current by causing the whole apparatus to rotate on the spindle by which it was supported. When, on the other hand, still air was to be examined, a current was ingeniously secured by means of a chimney conveying heated air from the flame of a spirit lamp.

In the first paper which Dr. Maddox published in reference to the use of this "aëroconiscope," he stated that by means of it he had been enabled to detect the presence of organic and mineral *débris*, pollen grains, minute germs of various fungi or protophytes, and excessively minute bodies, "molecules," or "globules," &c., in the atmosphere, but that a series of examinations, carried on during a period of 40 days, showed that, at the time and in the locality in which he was working, the air was by no means loaded with microscopic germs. The largest number visible in any collection of dust obtained by 24 hours'

---

[1] Monthly Microscopical Journal, vol. ii, p. 100.
[2] Op. cit., vol. iv, p. 68.
[3] Monthly Microscopical Journal, vol. ii, p. 253.
[4] Report on the Progress of Hygiene, by Dr. Parkes, Army Sanitary Report for 1867, p. 250.
[5] The Monthly Microscopical Journal, Vol. III, p. 286.

exposure of the apparatus was only 21, not including bacteroid bodies, and only a few of these germinated on being cultivated in suitable cells.

Pursuing his experiments sedulously during a period of months, Dr. Maddox arrived at numerous interesting results, among which were, that there was no special prevalence of germs with any special wind, nor any special relation between the force of wind and the quantity of spores, but that there was ample proof of the increase of dust in the air when the ground was dry, and that a gentle breeze was most productive in organic cells. The amount of spores detected in any single specimen varied from a maximum of 250 to a minimum of none, ranging through intermediate numbers of 112, 87, 60, &c. Only 46 varieties of vegetable germs were observed, the prevailing form consisting of pale olive-coloured oval cells, frequently associated with small round rather darker ones, and belonging apparently to some kind of smut. Observations were taken on 115 days in the months from April to November inclusive, and the largest results were obtained in July and August.[1]

Dr. Burdon Sanderson on the atmospheric germs of Fungi.

In the same year, whilst engaged in his researches on contagion, Dr. Burdon Sanderson tried a few experiments regarding the microscopic characters of atmospheric dust, and the presence of fungal germs in it.[2] Most of these only afforded negative results, as the amount of soot and dust present in the air in London obscured the preparations very greatly when Pouchet's method of collection was employed. Dr. Sanderson found the simple exposure of glass plates smeared with glycerine much better adapted for the purpose under such circumstances, and in such specimens found that it was always possible to discover a certain number of cells resembling torula cells, "and occasionally penicillium acrospores." Because he detected these, however, he did not conclude that fungi are generally propagated by such forms.

Dr. Sigerson's observations on the air of factories, &c.

Dr. Sigerson also published the results of his observations in 1870.[3] He examined the microscopic characters of the atmospheric dust deposited in various localities. In that of an iron factory he found a black dust consisting of carbon, ash, and iron. There were no spores or seeds to be detected in it, and no fibres save a few of cotton and of carbonaceous and metallic materials.

In the air of a shirt factory there were filaments of cotton and linen and a few minute ova, not generally dispersed through it, but occurring in small collections; in that of a thrashing mill, there were fragments of chaff and grain and some smut-balls; in that of oat-meal mills, fragments of grain and pericarp, and occasionally spores and acari; and in that of flax-mills, fragments of linen fibres. In stables, scales larvæ and eggs of moths, spores, cuticular scales, fragments of hair, and particles of blood-red colour, were found; in one specimen an acarus occurred. In the dust of a dissecting room, fragments of voluntary and involuntary muscles, portions of white and yellow fibrous tissue, epithelial scales, fat cells, corpuscles, fragments of hair, and abundant particles, were present. In the conclusion of his paper, the author remarks that the lungs have the power of absorbing and assimilating solid matters, and that "old lungs are grey from the dust they take up." He goes on to affirm that "there are no hosts of germs floating about in the atmosphere, and that "air is not much better, but not generally worse, than water" in this respect, and also alludes to a previous paper in which he had mentioned the existence of particles like exudation granules in the atmosphere of a patient suffering from fever.

Dr. Ransome on the organic matter of human breath.

In February 1870, Dr. A. Ransome read a paper before the Literary and Philosophical Society of Manchester "on the organic matter of human breath in health and disease."[4] In this he pointed out the great fallacy present in Mr. Dancer's calculations regarding the prevalence of spores in the air, and proceeded to detail the

[1] "The Monthly Microscopical Journal," Vol. V, p. 45.

[2] App. to "Thirteenth Report of the Medical Officer of the Privy Council." Dr. Sanderson had long been familiar with Pouchet's instrument, as Dr. Parkes in the Army Statistical, &c. Reports for 1860, mentions having obtained one from him.

[3] "A microscopic examination of the atmosphere." By George Sigerson, M.D., Ch.M., F.L.S. Member of Royal Irish Academy. "Monthly Microscopical Journal," Vol. IV, p. 93.

[4] "Nature" Vol. I, p. 520. "Popular Science Review," April 1870, p. 209.

results of his own experience in regard to the subject. As early as 1857 he experimented on the air by exposing glass plates covered with glycerine in various places and examining the dust deposited on them. By this means he was enabled to detect the presence of organised particles and fibres in the atmosphere of the dome of the Borough gaol. He drew the air of a crowded meeting into distilled water, and 36 hours after found fibres, cellules, nucleated cells surrounded by granular matter, and epithelial scales in it. He also examined common dust and fluid condensed from the breath. In five specimens of the latter very few spores were found, but after a few hours numerous spores and vibriones made their appearance. In a specimen derived from a case of diphtheria, greenish conferval filaments appeared, whilst in others from measles, whooping cough, and phthisis, abundant specimens of small round confervoid cells were present.

At the same meeting Dr. H. Browne stated that he also had made microscopic examinations of the air, and that his results had generally agreed with those of Dr. Ransome.

Mr. Tichborne's experiments on dust.

At the meeting of the British Association in 1870, Mr. C. R. C. Tichborne gave an account of his experiments on the atmosphere of Dublin, in a paper which subsequently appeared in the Chemical News for October of the same year.[1] He stated that street dust was mainly composed of stable manure and triturated stones. His experiments were almost entirely of a chemical nature, and showed the remarkable fact that dust taken at a great height in the air is just as active a ferment as that obtained from an overcrowded building, an apparent anomaly which he suggested might be due in some measure to the extreme levity of spores leading to their presence in large quantities in the higher strata of air.

Examination of dust in New York.

"The Scientific American" of 1870 furnished an account of the examination of air-dust by the New York Officers of Health.[2] Above 100 specimens were obtained by the exposure of glass plates to the air. The same substances were present in all of them, and consisted of street dust, particles of sand and carbon, fibres of cotton &c., fragments of vegetable tissues, granules of starch, three different kinds of pollen grains, and fungal elements. The latter were abundant, ranging in character from *micrococcus* to mycelial filaments. When water was added to the specimens, bacteria and vibriones invariably made their appearance within a few hours.

Selmi on Marsh-Miasm.

In Dr. Angus Smith's "Air and Rain"[3] various extracts are given from an Italian book by Selmi, of Mantua, on Marsh-Miasm, published at Padua in 1870. The author collected the moisture of the air of marshes by freezing, and found that, on standing, it showed a deposit consisting of myriads of spores of algæ and active infusoria.

Balestra on the fever of the Pontine marshes.

The Comptes Rendus for 1870[4] contained an account of Dr. Balestra's observations, which are alluded to by the author just mentioned. His experiments were conducted in Rome. In the air of the Pontine marshes, and even in that of Rome, he found the spores of a minute algal plant, of greenish-yellow colour, transparent and $\frac{1}{1000}$ m. m. in diameter. The plant grows in the water of Pontine marshes, and the spores were most abundantly present in the air in warm weather, and after rain or during a fog, least so at times when it was cool and dry. Dr. Balestra regarded them as the cause of intermittent fevers.

Messrs. Sidebotham and Stodder's experiments.

In the same year Mr. J. Sidebotham recorded the results of observations on the dust in a railway carriage[5] and Mr. Charles Stodder, of Boston, United States, those of others on the dust deposited on the beams of the polishing shop of the United States' Armoury at Spring field.[6]

---

[1] "Chemical News," October 21st, 1870, p. 197. "Dust as a ferment."
[2] "Popular Science Review," July 1870, p. 318.
[3] Page 514.
[4] Quoted in "Monthly Microscopical Journal," Vol. VIII, p. 34.
[5] "Monthly Microscopical Journal," Vol. VII, p. 18.
[6] Ibid, Vol. VII, p. 19.

The railway dust contained a very large proportion of fragments of iron, some long, thin, and straight, and many others more or less spherical. Cinders, bright fragments of glass or quartz, bits of yellow metal, grains of sand, bits of coal and opaque white spherical bodies, like those described by Dancer as occurring in the dust of flues, were also present.

Mr. Stodder's specimens contained a few vegetable fibres, some apparently organic fragments and a few crystals, but the great mass was composed of amorphous fragments of iron.

Professor Cohn on Bacteria.

Professor Cohn began at this time to publish the results of his renewed observations on bacteria (Bot. Ztg., 1871, No. 51), and has continued to do so at intervals since, in the proceedings of Silesian Society for National Culture and the "Beiträge zur Biologie der Pflanzen."

His experiments showed that chemical solutions when exposed to air were subject to be invaded by moulds, but usually escaped putrefaction.[1] He affirms that all the bacteria associated with contagious diseases belong to the motionless circular section of bacteria, and are frequently arranged in rosary-like chains.[2] They are also carried into the air in very large numbers by evaporating water. This fact can be easily demonstrated by covering any vessel containing a solution abounding in bacteria with a glass plate. The under-surface of the plate becomes coated with watery vapour, which can be collected into drops by the addition of ether, and on subsequent examination discloses the presence of bacteria.[3]

Dr. Eidam on Professor Rindfleisch's experiments.

Dr. Eidam states that Professor Rindfleisch's experiments also prove "that the atmospheric air usually contains no bacteria,"[4] and affirms that "it is known and satisfactorily proved, that in air enclosed in confined spaces in which decomposing organic substances are present, as also in that over swamps, bacteria, which have been carried up by the watery vapour, occur in abundance."

M. Charles Robin's account of atmospheric dust.

A very full account of atmospheric dust and of the more important questions relative to the nature of its constituents is to be found in Charles Robin's "Traité du Microscope."[5]

The author states that dust is composed of mineral, vegetable and animal particles; the mineral matters being principally calcareous and siliceous; the vegetable ones consisting of the *débris* of the tissues of plants, together with pollen grains, starch corpuscles, and the spores of cryptogams of various species; those of an animal nature being formed of fragments of minute articulate animals, hairs, scales of insects, portions of feathers or down, ovules of acari, &c., while there are also various undetermined azotised corpuscles, some of which are rounded and present the characters of entire dried infusoria. In regard to the fungal cells, he mentions that those occurring most frequently are bi-or multi-sporous thecæ or sporangia, superimposed in the form of brownish clubs and belonging to species of *Puccinia*, *Phragmidium*, &c., together with spores of other arthrosporous fungi, such as *Sporocadus*, *Bactridium*, *Septonema*, and *Cladosporium*.

In another passage, headed "*Des prétendus germes atmosphériques des infusoires*,"[6] he points out that only certain recognised ovules or germs of infusoria are known to exist, and that it is not impossible that such bodies may occasionally be present in the air, seeing that entire dried infusoria, bacillaria, bacteria and globules of pus have been found in dust, but that their presence has never been demonstrated. He then criticises Pasteur's statement

[1] "Quarterly Journal of Microscopical Science," April 1872, p. 208.

[2] In connection with this subject it may be mentioned that Dr. Parkes states in the fourth edition of his "Practical Hygiene" that Bakewell found minute scales of small-pox matter in the air of a small-pox ward, that Gailleton and Tilbury Fox detected the spores of *Tricophyton* in the air of wards containing cases of skin diseases, and that *Achorion* has been found in similar situations. He also alludes to the fact observed by Dr. Watson in the course of his observations on the air at Netley, that the atmosphere of a phthisical ward contained bodies resembling the degenerate cells of tubercle.

[3] "Der gegenwärtige Standpunkt der Mycologie," &c. Von Dr. Eduard Eidam, p. 201.

[4] Ibid, p. 199.

[5] Paris. J. B. Baillière et Fils. 1871, p. 528.

[6] Op. Cit., p. 821.

regarding the impossibility of distinguishing ova from spores, pointing out that they can be distinguished by means of re-agents, and that even the species to which a spore belongs may frequently be determined, and proceeds "du reste que ce soit la poussière recueillie dans l'air en mouvement ou déposée lentement, les spores, non plus que les filaments de mycelium, ne forment toujours que le plus petit nombre des corpuscles de celle-là, surtout à coté des fins granules grisâtres, tels que ceux dits *Micrococcus*[1] des grains de fécule, de silice &c., * * *. Quant aux Microphytes dont souvent, en effet le microscope, montre quelques spores, diverses de volume et de structure, rien n'est plus facile que de les distinguer, soit des ovaires ou des ovules des infusoires soit de ces derniers même enkystés ou non; rien n'est plus facile que de voir que les espèces de cryptogames auxquelles elles appartiennent ne dépassent pas une dizaine environ dans chaque expérience et qu'on n'en compte pas une centaine d'espèces, en comparant toutes les expériences faites."

Mr. Blackley's experiments on pollen in the air.

Mr. Blackley,[2] whilst working at the subject of Hay Asthma, made numerous observations on atmospheric particles. He investigated the amount of pollen in the air by exposing slips of glass for a given length of time. A cell coated with glycerine was on each glass, and the number of pollen grains deposited in it during 24 hours was counted. The number of grains present increased from the beginning until towards the end of June, when the grass is chiefly in flower. More pollen was found in hot dry days than in damp weather, and some of the experiments proved that the grains were sometimes carried for long distances through the air. His experiments also proved the presence of more pollen grains in elevated strata of air than in those close to the surface of the ground, a result of much interest when taken in connection with Mr. Tichborne's observations previously quoted, and in regard to the question of the diffusion of the causes of disease by atmospheric currents.

Such are the greater number of the observations on record in regard to this important subject. The majority of them are referable to one of two classes, according to the aim with which they were undertaken, according as they were designed to throw light on the question of the causation of disease on the one hand or on that of the origin of life on the other. The results and conclusions arrived at by their means differ in various respects, and in many cases are directly contradictory. They also form two great classes, according as they respectively affirm or deny the existence of organisms or their germs in the atmosphere. Those of MM. Quatrefages, Pasteur, Samuelson, Angus Smith and others belong to the former section, whilst those of Pouchet may be taken as a type of the latter. Even among those maintaining the existence of atmospheric organisms, however, there are minor differences, some affirming the presence of vegetable organisms only, or almost only (Robin), and others that of infusorial animalcules, their germs and ova, in equal or even in greater proportion (Ehrenberg). Some of these discrepancies are capable of explanation if the various methods of experiment employed by different observers be taken into account, but, before entering farther into a discussion regarding them, the observations which form the subject of the present Report may be detailed, as it is possible that they may throw some light on the matter.

---

[1] When describing the changes occurring in animal fluids after their escape from the body, he defines what the bodies are which he includes under the term "*Micrococcus*," stating that as a primary change there is a gradual formation "de fins granules grisâtres à peine perceptibles, doués d'un mouvement brownien très-vif. Là aussi il faut noter le dépôt sur les cellules épithéliales et autres éléments en suspension dans le liquide, de couches uniformes de granules d'un aspect analogue à celui des précédents (*Micrococcus, &c.*) tous contigus et couvrant la surface de ces éléments."

[2] "Experimental researches on the causes and nature of *Catarrhus Æstivus* (Hay Fever or Hay Asthma) by Charles H. Blackley, M. R. C. S., London, 1873, London Medical Record, June 1873, p. 371 (Review).

SECTION II.

SYSTEMATIC OBSERVATIONS ON ATMOSPHERIC DUST IN DEFINITE LOCALITIES.

A systematic and prolonged series of observations was carried on within the two large Jails in Calcutta, with the view of determining, if possible, whether there were any connection traceable between the prevalence of any special bodies in the atmosphere and the occurrence of particular forms of disease. In regard to this question, it is evident that, even were such a coincidence demonstrated, it would by no means necessarily imply any direct causal connection between the two phenomena. A disease might really be dependent on atmospheric causes, and its prevalence might coincide with the presence of peculiar atmospheric particles, and yet the former be quite independent of the latter. At the same time, even allowing this, in the case of diseases dependent, not on any specific material manufactured within the human organism and transferred from person to person, but on external conditions,—it is quite conceivable that the presence of certain particles in the atmosphere might serve as an index to the probabilities in favour of the prevalence of disease; as the conditions producing the latter, or the special cause of the latter, might also favour development of organisms capable of furnishing characteristic solid particles to the atmosphere. This is a point of view which appears to have been greatly lost sight of by those who have endeavoured to connect the occurrence of diseases, more especially those provisionally termed malarial fevers, with the prevalence of special atmospheric organisms.

Observations on atmospheric particles in reference to the occurrence of disease.

As was previously stated, the observations about to be detailed were limited to the microscopic characters of common atmospheric dust, with the aim of securing data for comparison in future observations on special atmospheres, such as those of buildings, &c. The two jails were selected as localities for observation, on the grounds that their inmates are subject to much more fixed and ascertainable conditions than any class of the outside population, and that their statistics of disease for particular periods are almost absolutely accurate. In regard to any series of observations carried on in definite localities, there is one great disadvantage which cannot in any way be overcome. It is impossible within a fixed period to secure the prevalence of all the diseases in regard to which the enquiry is instituted. The force of this comes out very distinctly in the present instance, for in one of the localities of observation—the Alipore Jail, which in former years used to furnish so many cases of cholera—only 11 cases of cholera and choleraic diarrhœa occurred during the period regarding which particulars are here given, and these were spread over six different months. This is no doubt unfortunate, but the disadvantage appears to be more than counterbalanced by the value of the data furnished by such systematic observations in other ways; for any series of observations confined to the period of prevalence of any special disease are entirely wanting in the essential element of comparison, and are, therefore, almost totally valueless. Unless the characteristics of periods of prevalence can be compared with those of periods of immunity, there are no grounds for coming to any definite conclusions regarding the significance of special phenomena. It is only by a prolonged series of observation, too, that the influence of season on the nature of atmospheric particles can be determined, and until this has been done, there must remain a constant liability to error, due to the occurrence of deceptive coincidences.

Localities selected for observation.

The observations were fifty-nine in number, the date of the first being the 26th of February, and that of the last the 18th of September 1872. Thirty of them were taken at Alipore and twenty-nine in the Presidency Jail. During the first month there was some slight irregularity in the order in which they were taken, but

System on which observations were conducted.

subsequently observations were taken alternately in each locality. Greater frequency in observation would, no doubt, have been desirable, and daily observations in each would alone have rendered the series perfect, but this was practically out of the question, as it was soon found that regular weekly observations demanded as much time for their thorough and efficient performance as could be given to them without an entire abandonment of other work.

The apparatus employed in obtaining specimens was a slightly modified form of that devised by Dr. Maddox, and described in the account of his experiments. It consisted (*vide* Fig. 1 A) of three thin brass tubes, two

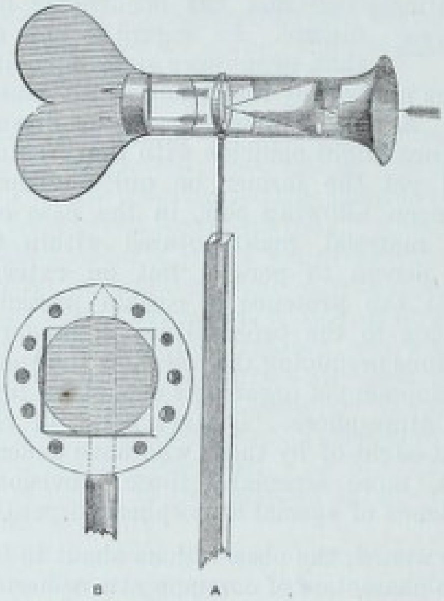


FIG. 1.—Apparatus employed in collecting specimens of atmospheric dust.

of which slipped over the third central one and came into contact with the opposite sides of a projecting rim on its circumference. This rim was formed by the margin of a diaphragm which divided the centre tube into two chambers. It was of sufficient thickness to allow of a spindle passing up through it (B). The latter terminated in a pointed extremity, which came in contact with the upper end of the bearing, and provided for the free rotation of the system of tubes. Round the margins of the diaphragm there was a set of perforations, to allow of the passage of air through it, and, on the centre of its anterior surface, there was a square plate of brass with a slightly projecting rim on its lower margin. The anterior of the two lateral tubes was provided with an expanded orifice, and contained a small, finely-pointed funnel in its interior; the pointed extremity opening immediately in front of the centre of the diaphragm-plate. The posterior tube was quite simple, and had a good sized fish-tail vane fitted into a slit in its extremity.

Description of apparatus for collection of atmospheric dust.

At each of the localities selected as sites for observation, a stout teak-wood post about $4\frac{1}{2}$ feet in height was firmly fixed into the ground. A brass spindle fitting the bearing in the diaphragm of the apparatus was screwed into the top of each of them, and served as an axis of rotation, securing the exposure of the expanded orifice of the apparatus to the prevailing currents of wind. Preparatory to taking any observations, the apparatus was well washed with spirits of wine and heated over a spirit lamp. A microscopic cover-glass of suitable size was then carefully cleaned, and one surface smeared with pure glycerine. A minute drop of the same medium was placed upon the diaphragm-plate, and the dry surface of the cover-glass applied to it, leaving the smeared surface exposed. The glycerine on the diaphragm secured the glass adherent in a vertical position, and did away with any necessity for a spring, the use of which was found

Method in which it was employed.

inconvenient from its coming in the way and intercepting more or less of the atmospheric dust. The anterior tube was next slipped on, bringing the pointed extremity of the interior funnel immediately in front of the glass, and the whole apparatus was finally set on the spindle, where it remained during a period of twenty-four hours.

Sites of apparatus in the two localities selected.

In the Presidency Jail the supporting post was placed within the largest enclosure, on an open space of grass to the east of a large tank in which the native prisoners bathe. The most convenient locality at Alipore was found to be the compound of the jail hospital, and the post was accordingly fixed there, to the north of the hospital tank between it and the tidal nullah, from which it was separated by the posterior wall of the enclosure. The mouth of the apparatus, when *in situ*, was at a level of about 5 feet from the ground, that elevation being chosen as likely to correspond with the stratum of air breathed by a man whilst in an erect position, and, therefore, likely to show the nature of the atmospheric particles commonly entering the respiratory passages.

Method of examining and recording characters of specimens.

At the close of twenty-four hours the apparatus was taken down, the anterior tube removed, and the cover-glass transferred to a clean slide; a little fresh glycerine being added if necessary. The upper surface was then carefully cleaned of any remains of glycerine, and the preparation was ready for examination. The latter consisted in systematically working over every portion of it, noting and recording the general features presented by it, and in the majority of instances, where the numbers present were not too great, in drawing to scale all the spores, fungoid and algoid cells, pollen grains and any bodies resembling the cysts or ova of infusoria which could be detected. This necessarily involved the expenditure of much time, but it was very soon found to be the only satisfactory means of preserving a distinct record of the characters of individual specimens of such a nature as to permit of the comparison of one with another. These illustrations have been admirably reproduced in the accompanying plates prepared in the Surveyor General's Office, furnishing a representation of the characters of the bodies present in the various experiments, advantageously substituting a large amount of descriptive writing, which would otherwise have been necessarily introduced without in the end so satisfactorily affording the desired information as is done by their means. As a general rule, the magnifying power employed in the microscopical examination of the preparations was one of 400 diameters, but wherever necessary in the examination of specimens, such as minute fungoid cellules or bacteroid bodies, this was replaced by others ranging from 800 to 1,000 diameters.

TABLE I.—*Observations at*

Date.	Wind.		Rainfall of 3 days.	Mean degree of humidity.	Number of spores, &c., present.	Statistics of disease for 3 days previous.					
	Prevailing direction.	Velocity. Miles.				Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.
February 29 ...	S. S. W. & S. ...	133·5	0·0 0·0 0·0	0·75	237	3,012	3	2	...	1	...
March 7 ...	S. by W., E. S. E. & S. S. W.	122·5	0·21 0·0 0·0	0·72	107	2,957	2	5	...	3	...
" 14 ...	S. W. & W. N. W. ...	98·8	0·0 0·0 0·0	0·60	224	2,938	2	7	...	8	...
" 18 ...	W. S. W. & W. N. W. ...	110·8	0·0 0·0 0·0	0·59	211	2,941	3	1	...	4	...
" 25 ...	S. & S. S. W. ...	161·0	0·0 0·0 0·0	0·68	137	3,003	3	5	...	5	...
April 1 ...	S. by E. & variable ...	81·2	0·0 0·39 0·0	0·79	84	3,028	1	7	...	4	...
" 14 ...	S. & S. by W. ...	133·1	0·0 0·0 0·0	0·64	75	3,032	7	...	...	13	2
" 22 ...	S. by W. & S. S. W. ...	315·8	0·0 0·0 0·05	0·71	81	3,062	1	5	...	7	5
" 28 ...	S. & S. by W. ...	208·3	0·0 0·0 0·73	0·70	42	3,116	1	2	...	10	7
May 5 ...	S. by W. & S. S. W. ...	312·2	0·0 0·0 0·0	0·70	108	3,226	2	...	...	8	15
" 12 ...	E. S. E. & S. S. W. ...	167·2	0·0 0·0 0·0	0·73	67	3,244	1	2	...	32	5
" 22 ...	W. S. W. & S. W. ...	143·7	0·0 0·12 0·0	0·73	155	3,265	...	...	...	31	1
" 27 ...	S. by E. & S. ...	196·5	0·0 0·0 0·0	0·72	83	3,237	1	2	...	14	1
June 3 ...	S. by E. & S. ...	345·3	0·0 0·0 0·0	0·68	62	3,296	2	1	...	13	...
" 9 ...	S. by W. & S. ...	212·9	0·07 0·38 0·67	0·81	149	3,310	5	5	...	9	...
" 16 ...	S. S. E. & S. ...	151·2	0·33 0·09 0·0	0·81	195	3,340	3	2	...	4	...
" 23 ...	E. by S. E. & S. S. E. ...	214·6	0·17 0·17 0·05	0·88	315	3,377	1	2	...	6	...
" 30 ...	E. N. E. & E. by N. ...	385·2	0·13 0·23 0·64	0·89	272	3,388	5	3	...	3	...
July 7 ...	S. by E. & S. ...	24·6	0·0 0·0 0·0	0·82	90	3,388	3	1	...	11	...
" 12 ...	Variable ...	109·9	0·26 0·13 0·17	0·91	232	3,401	8	3	4	5	...
" 21 ...	S. S. E. & S. ...	66·2	0·13 0·0 0·40	0·87	123	3,308	3	4	...	13	...
" 28 ...	S. S. W. & S. W. ...	173·4	0·04 0·03 0·39	0·90	292	3,288	4	...	...	14	...
August 4 ...	S. by E. & S. ...	127·8	0·19 0·41 0·34	0·88	137	3,353	...	2	...	9	...
" 11 ...	S. by W. & S. S. W. ...	72·2	0·26 0·03 0·0	0·88	73	3,324	...	2	...	10	...
" 18 ...	S. W. & S. S. W. ...	67·0	0·0 0·0 0·0	0·81	380	3,379	1	9	...	11	...
" 25 ...	S. E. ...	100·8	0·09 0·10 0·94	0·91	213	3,401	4	3	...	14	...
September 1 ...	S. S. W. ...	154·2	0·98 1·05 0·0	0·93	116	3,487	1	4	...	10	...
" 8 ...	W. S. W. & W. by S. ...	22·5	0·19 0·0 0·0	0·83	280	3,547	1	6	...	12	...
" 15 ...	S. S. E. & E. S. E. ...	93·2	0·20 0·20 0·0	0·83	81	3,537	3	4	...	8	...

the Presidency Jail.

Statistics of disease of the day.						Statistics of disease for 3 days after.						Statistics of disease for the week.						Plate and Fig.	
Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.	Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.	Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.		
993	2	3	...	3	...	2,959	1	1	...	2	...	6,964	6	6	...	6	...	I	1
993	2	...	...	2	...	2,950	5	3	...	4	...	6,900	9	8	...	9	...	,,	2
984	4	2	...	...	...	2,941	3	1	...	4	...	6,863	9	10	...	7	...	,,	3
980	1	1	...	3	...	2,958	4	1	...	3	...	6,879	8	3	...	10	...	,,	4
991	5	1	...	2	...	3,070	3	2	...	12	...	7,064	11	8	...	19	...	,,	5
1,007	...	...	...	3	...	3,032	1	2	...	6	...	7,067	2	9	...	13	...	III	1
1,010	1	1	...	3	1	3,038	5	1	...	12	5	7,080	13	2	...	28	8	,,	
1,025	...	4	...	6	2	3,060	...	4	...	17	7	7,147	1	13	...	30	14	,,	3
1,074	...	2	...	5	2	3,232	3	2	...	6	28	7,422	4	6	...	21	37	,,	4
1,078	...	...	...	3	1	3,227	2	...	...	16	9	7,531	4	...	...	27	25	V	1
1,084	2	2	...	1	...	3,248	...	1	...	21	...	7,576	3	5	...	54	5	,,	2
1,091	1	...	...	11	...	3,247	...	...	...	20	1	7,603	1	...	...	62	2	,,	3
1,074	...	...	...	6	1	3,234	1	7	...	12	2	7,545	2	9	...	32	4	,,	4
1,102	...	...	...	5	...	3,313	2	3	...	16	1	7,711	4	4	...	34	1	VII	1
1,102	1	1	...	...	...	3,304	2	1	...	11	...	7,716	8	7	...	20	...	,,	2
1,114	...	1	...	...	...	3,360	3	5	...	14	...	7,814	6	8	...	18	...	,,	3
1,131	...	...	...	...	...	3,380	1	2	...	3	...	7,888	2	4	...	9	...	,,	4
1,123	...	...	1	...	1	3,364	4	2	4	5	...	7,875	9	5	5	8	1	IX	1
1,134	1	2	2	1	...	3,400	5	4	2	4	...	7,922	9	7	4	16	...	,,	2
1,132	2	...	...	5	...	3,403	4	3	2	11	...	7,936	14	6	6	21	...	,,	3
1,083	...	...	...	1	...	3,277	5	3	...	13	...	7,668	8	7	...	27	...	,,	
1,095	1	...	...	4	...	3,325	5	7	...	10	...	7,708	10	7	...	28	...	XI	1
1,110	1	...	...	1	...	3,349	4	1	...	5	...	7,812	5	3	...	15	...	,,	2
1,110	...	1	...	1	...	3,377	1	4	...	11	...	7,811	1	7	...	22	...	,,	3
1,128	...	1	...	5	...	3,398	...	8	...	17	...	7,905	1	18	...	33	...	,,	4
1,139	...	1	..	3	...	3,436	3	4	...	10	...	7,976	7	8	...	27	...	XIII	1
1,179	...	2	...	6	...	3,536	3	3	...	23	...	8,202	4	9	...	39	...	,,	2
1,176	...	3	1	2	...	3,534	1	5	...	14	...	8,257	2	14	1	28	...	,,	3
1,179	...	...	...	4	...	3,544	4	6	...	13	...	8,260	7	10	...	25	...	,,	4

TABLE II.—*Observations*

Date.	Wind.		Rainfall of 3 days.	Mean degree of humidity.	Number of spores, &c., present.	Statistics of diseases for 3 days, previous.					
	Prevailing direction.	Velocity. Miles.				Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.
February 26 ...	W. S. W. & S. W. ...	93·4	0·0 0·0 0·0	0·67	117	6,218	5	3	...	1	...
" 27 ...	S. S. W. & S. W. ...	67·7	0·0 0·0 0·0	0·68	81	6,231	7	3	1	2	...
March 4 ...	W. & W. S. W. ...	122·0	0·0 0·0 0·0	0·58	78	6,188	4	2	1*	1	...
" 11 ...	S. W. ...	185·9	0·0 0·0 0·0	0·66	269	6,149	1	...	...	5	...
" 20 ...	S. S. W. & S. by W. ...	98·0	0·0 0·0 0·0	0·68	94	6,220	7	2	...	1	...
" 28 ...	S. S. W. & S. by W. ...	151·8	0·0 0·0 0·0	0·68	263	6,417	5	4	...	2	...
April 3 ...	W. S. W. & S. S. W. ...	128·7	0·0 0·02 0·34	0·74	73	6,264	4	2	...	3	...
" 17 ...	Variable ...	99·1	0·0 0·0 0·02	0·52	169	6,198	3	...	...	10	...
" 24 ...	S. E. & S. S. W. ...	205·1	0·05 0·28 0·0	0·75	233	6,262	4	2	...	2	5
" 30 ...	S. S. W. & S. by W. ...	277·9	0·73 0·0 0·0	0·72	163	6,219	5	4	...	4	2
May 8 ...	S. S. E., S. by W. & S. ...	102·8	0·0 0·0 0·0	0·73	94	6,393	1	...	...	7	2
" 15 ...	S. S. W. & S. by W. ...	290·5	0·0 0·0 0·08	0·68	107	6,396	2	4	...	3	2
" 24 ...	S. & S. by W. ...	193·0	0·0 0·04 0·0	0·72	111	6,583	1	1	...	1	1
" 29 ...	S. by W. & S. ...	182·2	0·0 0·0 0·0	0·70	112	6,539	4	4	...	5	5
June 5 ...	S. & S. by W. ...	343·2	0·0 0·33 0·0	0·71	144	6,542	5	6	...	2	4
" 12 ...	S. by E., S. W. & S. S. E....	183·0	0·40 0·03 0·64	0·87	272	6,618	7	4	1	10	11
" 20 ...	S. by E. & S. S. E. ...	94·2	0·0 0·0 0·66	0·74	72	6,580	10	1	...	3	7
" 26 ...	E. S. E. & E. by N. ...	207·0	0·92 0·45 0·04	0·90	133	6,482	12	7	...	1	3
July 3 ...	S. S. W. ...	327·0	0·43 0·07 0·0	0·85	231	6,593	11	3	...	5	4
" 10 ...	Variable ...	255·6	0·08 0·11 0·26	0·84	267	6,672	16	10	...	1	8
" 17 ...	S. & S. by W. ...	62·6	0·12 0·13 0·08	0·85	35	6,706	10	12	...	4	8
" 24 ...	E. & S. S. E. ...	116·5	0·04 0·25 0·63	0·89	323	6,709	17	15	...	...	2
" 31 ...	W. & S. ...	58·8	0·27 0·02 0·07	0·85	102	6,665	6	5	...	...	3
August 7 ...	S. S. E. & S. ...	153·2	0·56 0·25 0·51	0·90	318	6,699	5	10	1*	2	3
" 14 ...	S. ...	65·3	0·35 2·42 2·20	0·90	169	6,710	7	10	...	3	1
" 21 ...	W. by S. & S. S. W. ...	45·0	0·30 0·58 0·23	0·91	262	6,702	10	6	...	7	1
" 29 ...	S. & S. E. ...	91·5	0·0 0·0 0·04	0·83	110	6,678	9	8	...	3	1
September 4 ...	S. W. & S. S. W. ...	148·6	0·0 0·75 0·67	0·83	288	6,667	3	11	...	3	3
" 11 ...	N. W. & N. by W. ...	253·4	0·0 0·0 1·36	0·80	174	6,657	10	6	...	8	3
" 18 ...	S. E. & Variable ...	65·2	0·12 0·0 0·50	0·76	71	6,743	4	2	...	...	...

* Cases marked thus are cases of choleraic diarrhœa.

at Alipore.

Statistics of diseases for the day.						Statistics of diseases for 3 days after.						Statistics of diseases for the week.						Plate and Fig.	
Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.	Number of prisoners in Jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.	Number of prisoners in jail.	Cases of Diarrhœa.	Cases of Dysentery.	Cases of Cholera.	Cases of Ague.	Cases of Dengue.		
2,071	4	...	1	...	...	6,210	4	1	...	...	...	14,499	13	4	1	1	...	II	1
2,061	1	1	...	...	...	6,187	7	...	...	...	...	14,479	15	4	1	2	...	„	2
2,061	2	...	...	1	...	6,167	4	2	...	2	...	14,416	10	4	1*	4	...	„	3
2,060	3	1	...	1	...	6,162	7	3	1*	4	...	14,371	11	4	1*	10	...	„	4
2,099	2	3	...	1	...	6,281	2	...	...	4	...	14,600	11	5	...	6	...	„	5
2,133	2	3	...	2	...	6,389	4	3	...	1	...	14,939	11	10	...	5	...	„	6
2,058	2	...	...	1	...	6,163	2	2	...	3	...	14,485	8	4	...	7	...	IV	1
2,077	2	1	...	3	...	6,263	4	1	...	14	...	14,538	9	2	...	27	...	„	2
2,121	...	...	...	...	...	6,205	3	4	...	10	2	14,588	7	6	...	12	7	„	3
2,074	1	...	...	4	2	6,225	2	3	...	5	3	14,518	8	7	...	13	7	„	4
2,125	...	1	...	1	...	6,404	1	1	...	4	3	14,922	2	2	...	12	5	VI	1
2,132	1	1	1*	1	3	6,444	4	7	...	...	2	14,972	7	12	1*	4	7	„	2
2,179	1	...	...	...	1	6,545	3	2	...	5	3	15,307	5	3	...		5	„	3
2,172	3	1	...	...	...	6,526	4	6	...	10	3	15,228	11	11	...	15	8	„	4
2,175	3	1	...	1	2	6,578	5	2	...	...	11	15,295	13	9	...	3	17	VIII	1
2,202	4	3	1	5	1	6,645	2	2	1*	4	...	15,465	13	9	3†	19	12	„	2
2,167	3	...	...	...	...	6,499	7	4	...	...	4	15,246	20	5	...	3	11	„	3
2,181	4	1	...	2	1	6,590	18	6	...	1	7	15,253	34	14	...	4	11	„	4
2,195	2	2	...	...	3	6,605	12	10	...	...	–	15,393	25	15	...	5	7	X	1
2,231	3	5	...	...	1	6,692	8	7	...	...	5	15,595	27	22	...	1	14	„	2
2,241	7	1	...	...	1	6,720	8	7	1*	2	5	15,667	25	20	1*	6	14	„	3
2,232	3	3	...	1	...	6,666	10	9	...	1	2	15,697	30	27	...	2	4	„	4
2,215	...	5	...	...	1	6,675	3	1	...	2	...	15,555	9	11	...	2	4	XII	1
2,239	8	5	...	...	...	6,713	6	5	1*	3	5	15,651	19	20	2*	5	8	„	2
2,234	6	...	...	...	1	6,678	7	11	...	...	2	15,622	20	21	...	3	4	„	3
2,241	1	...	...	4	1	6,728	5	5	...	2	...	15,671	16	11	...	13	2	„	4
2,213	...	2	...	...	...	6,649	8	3	...	...	...	15,540	17	13	...	3	1	XIV	1
2,220	3	1	...	3	3	6,655	11	7	...	3	5	15,542	17	19	...	9	11	„	2
2,222	1	2	...	3	2	6,712	3	7	...	1	1	15,591	14	15	...	12	6	„	3
2,232	...	1	...	1	...	6,698	2	5	...	4	...	15,673	6	8	...	5	...	„	4

* Choleraic diarrhœa.

† One, a case of choleraic diarrhœa.

In order as much as possible to reduce some of the more important results of the entire series of experiments to a convenient and intelligible form, the accompanying tables and diagrams have been drawn up, containing a summary of them. A separate table has been given for each locality rather than a conjoint one for both, because one of the latter nature would not have so readily afforded information in regard to points connected with the local distribution of disease according to time. The first column in each table contains the date of observation, the second the prevailing direction of the wind, the third the velocity of the wind, the fourth the rainfall, the fifth the mean degree of humidity, and the sixth the number of fungoid and algoid cells and of pollen grains present, while the rest are occupied with statistics relative to jail population and prevalence of disease. The meteorological data are derived from the "Results of the meteorological observations taken at the Surveyor General's Office," and published weekly in the *Calcutta Gazette*, and none of the columns of the table containing them appear to require any special explanation save the fourth. This contains the rainfalls for three successive days, corresponding to each period of observation; the rainfall of the day previous to that of observation is registered, because it may be supposed to exert an important influence for some time after its occurrence, and that of the day following, because the periods of observation and those for which rainfall is registered did not coincide, so that a fall occurring on the day subsequent to that from which an observation is dated might in many instances have partially or even totally occurred during the period in which the apparatus was exposed. Of the four diagrams the two upper ones show the relations existing between the velocity of the wind and the number of spores, &c., collected, and the two lower refer to the latter phenomenon and the prevalence of certain forms of disease.

Description of tables and diagrams.

Before proceeding to the discussion of any of the special questions in connection with the various bodies occurring in these preparations, some general points regarding the whole series may be briefly alluded to. The amount of dust visible to the naked eye varied extremely; in some cases being almost or entirely inappreciable, in others present in considerable quantity, whilst in one or two cases in which dust-storms had occurred during the period of exposure, the amount was so great as actually to form a small heap opposite the orifice of the funnel, and to require the addition of a considerable quantity of fresh glycerine ere contact between the slide and cover could be secured. The relative proportions of the various classes of microscopic constituents present also varied, an increase in one of them being by no means necessarily or invariably associated with an increase in others. For example, dry windy weather caused a great increase in the amount of silicious, carbonaceous, and amorphous particles and other *débris*, but certainly did not cause a proportionate increase in the number of spores and other fungal and algal cells. On the other hand, the occurrence of moist weather was accompanied by a great diminution in the quantity of the former without in many cases appearing to influence the numbers of the latter at all, or in a similar direction. Where a very large quantity of coarse dust and amorphous matter is present, it is no doubt often difficult to determine the absolute numbers of the spores, &c., in a preparation, but it is, at all events, easy to see that the increase of them, if it exist, is not proportional.

Coarse dust: its amount at various times.

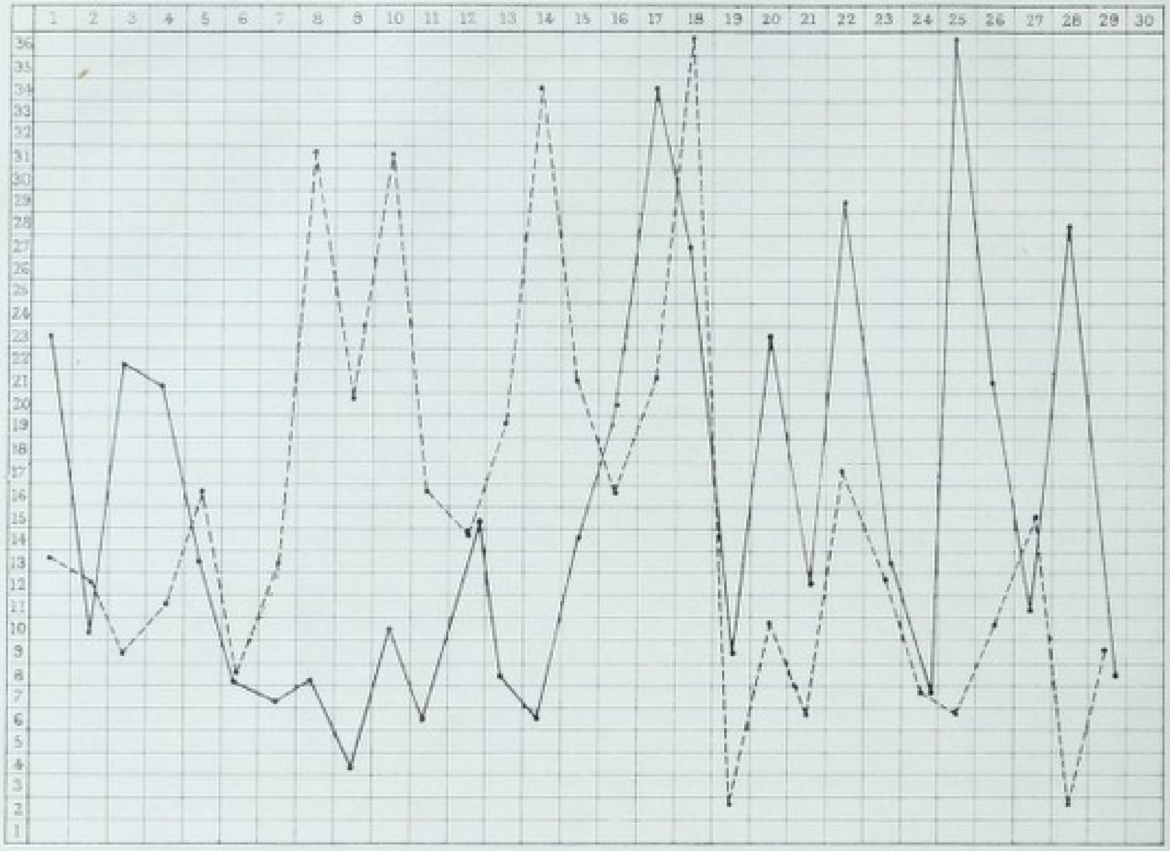
The influence of moisture in diminishing the numbers of the coarser atmospheric particles is evident when the following statement is compared with the tables at pages xxii, xxiv.

Influence of moisture on coarser constituents of atmospheric dust.

Amount of dust visible to the naked eye in 59 *Preparations.*

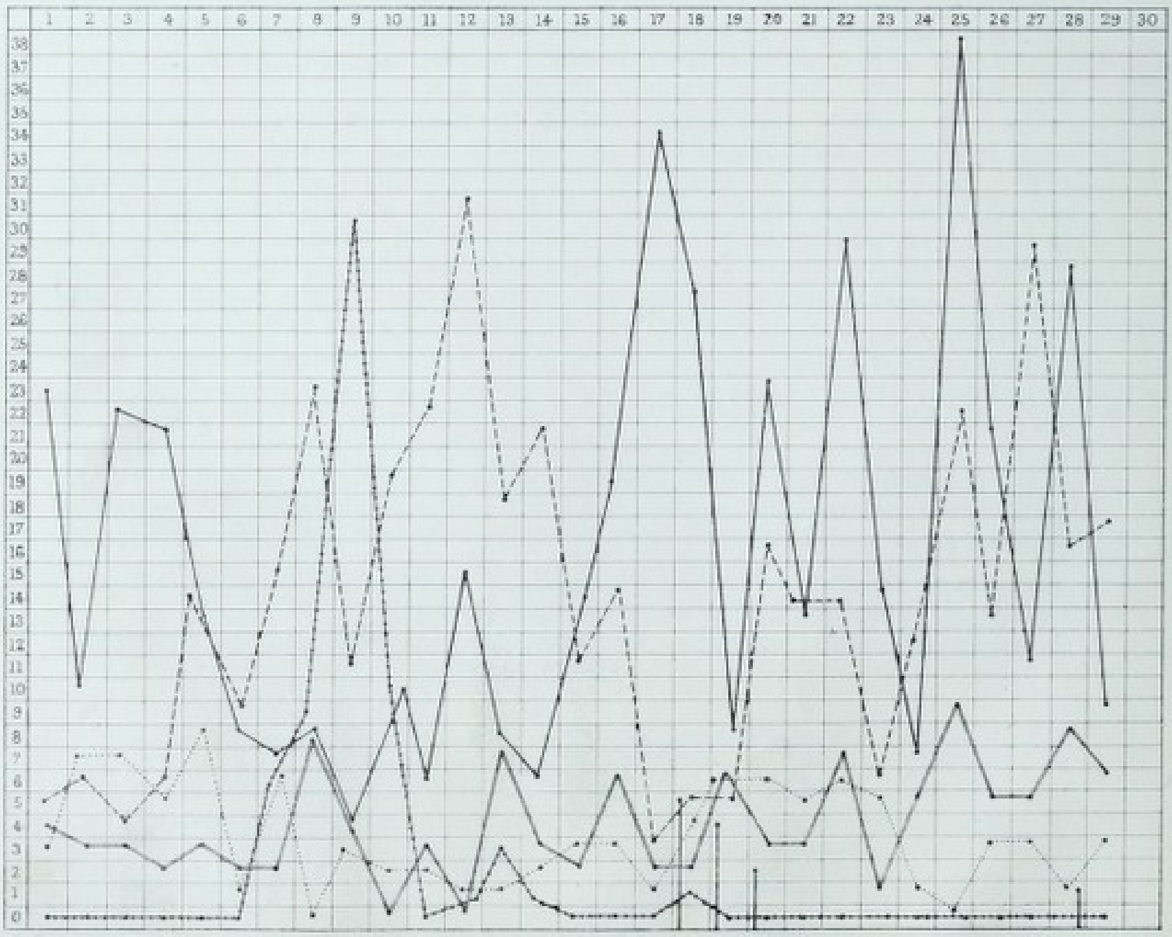
Of 29 Preparations from February 26th to June 5th.	Of 30 Preparations from June 9th to September 18th.
16 contained an abundance. 13 ,, a little.	3 contained an abundance. 3 ,, a little. 19 ,, a mere trace. 5 ,, none.

DIAGRAM I.



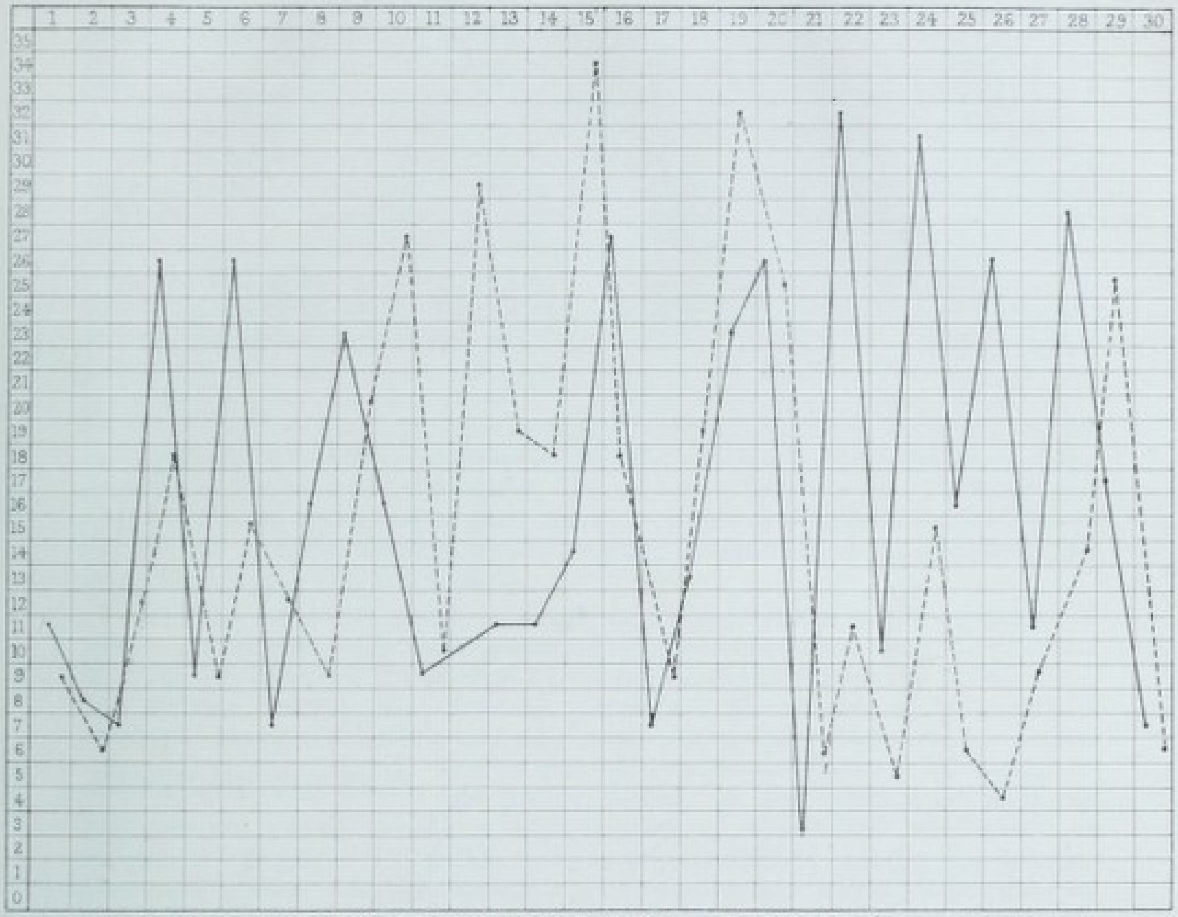
VELOCITY OF WIND AND NUMBERS OF SPORES &c. AT THE PRESIDENCY JAIL { —— Spores &c. - - - - Velocity of wind.

DIAGRAM II.



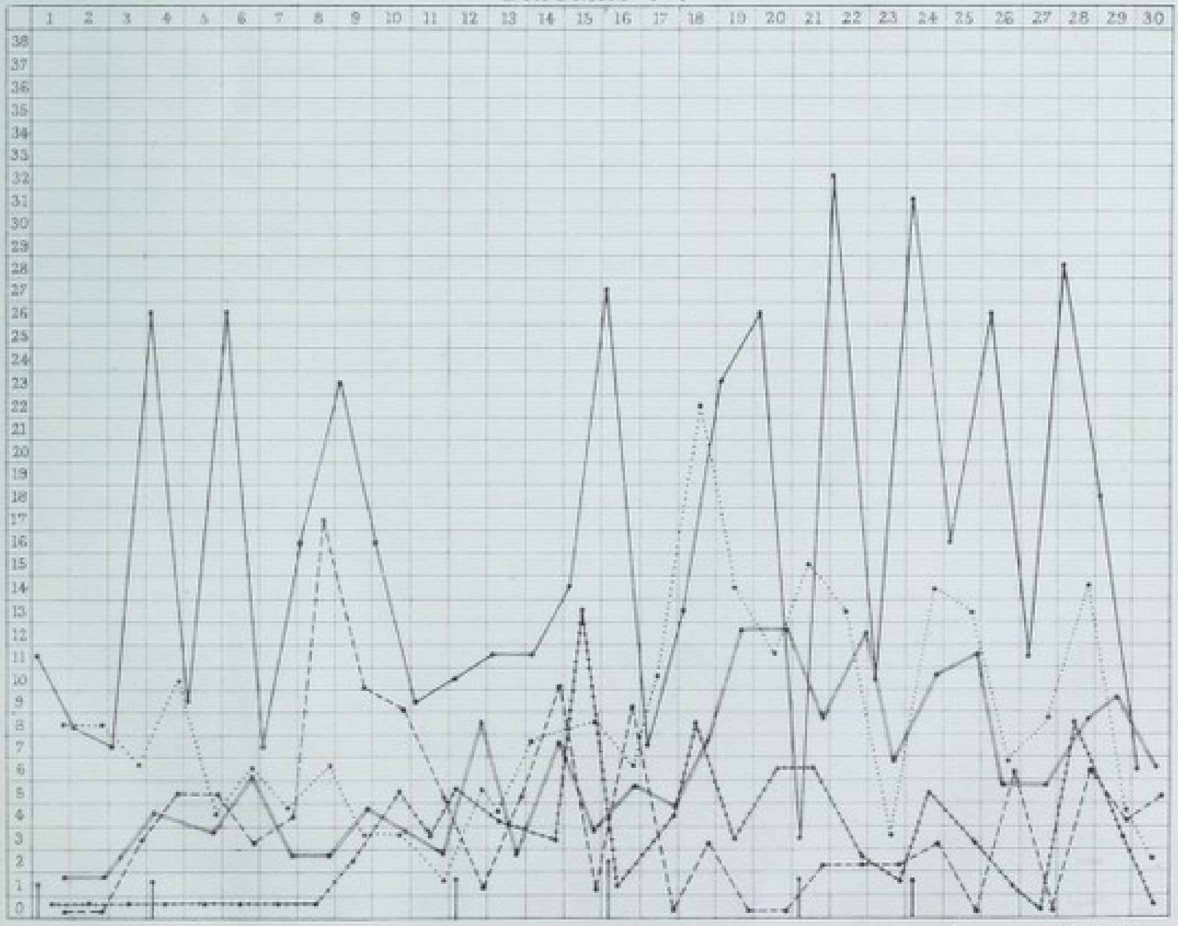
NUMBERS OF SPORES &c. AND OF CASES OF FIVE DISEASES AT THE PRESIDENCY JAIL { Spores &c. Ague Dysentery Diarrhœa Dengue Cholera

DIAGRAM III.



VELOCITY OF WIND AND NUMBERS OF SPORES &c. AT ALIPORE { —— Spores &c. / - - - - Velocity of wind.

DIAGRAM IV.



NUMBERS OF SPORES &c. AND OF CASES OF FIVE DISEASES AT ALIPORE { Spores &c. / Ague / Dysentery / Diarrhœa / Dengue / Cholera

Turning now to the tables, it will be seen that rain is registered on 10 periods of observation up to the 5th June, and on 28 from that date to the 18th September, inclusive. On comparing the total rainfalls of the two periods, the difference comes out even more strongly, for, whilst the total rainfall of the former only amounted to 4·36 inches, that of the second amounted to 32·26 inches; rain falling on 15 of the 101 days of the one, and on 77 of the 105 days included in the other. While, however, moisture exerts such a decided influence on the amount of the coarser inorganic and amorphous particles in the atmosphere, it does not appear to affect that of the spores, &c., in the same manner, but, on the contrary, rather tends to increase it, for it will be seen that the number of such bodies present exceeded the average in 17 instances during the moist period and only in 8 during the dry one. This statement must not be regarded as implying that actual heavy rainfall does not temporarily diminish the number of spores and similar cells in the air, for there can be no doubt that it really does so; but, while the effect on the inorganic and amorphous constituents persists until the drying up of the surfaces from which they are derived, spores, &c., at once begin to be developed and added to the air anew, and in many cases, in larger numbers than previously, due to the stimulus afforded by the presence of moisture to the growth of the fungi from which they are derived.

Velocity of wind: no evident influence on numbers of spores, &c.

Velocity of wind seems to exert as little influence on the numbers of spores and similar cells in the atmosphere as moisture, for during the first and dry period it exceeded the average 14 times, and during the second moist period only 9 times, and yet, as previously mentioned, the number of preparations obtained during the latter containing spores above the average, was more than double that of similar preparations belonging to the former period. A low velocity, too, in many instances was coincident with a high number of spores and *vice versâ*, as appears in diagrams I and III, showing the relations of velocity and number graduated by tens. At the same time, in a considerable majority of instances, a rise or fall in velocity was accompanied by a corresponding rise or fall in the number of spores. This occurred in 33 cases against 24, but does not seem to imply any absolute increase in number dependent on increased velocity; for as the quantity of air traversing the aeroscope in a given time necessarily augments with augmented velocity of wind, a greater number of spores may be deposited in it in a given time, even coincident with the presence of a diminished number in a given bulk of air. No special influence of direction of wind can be made out from the tables, but this may, perhaps, be partially due to the comparatively slight amount of variation occurring during the periods of observation.

Varying influence of velocity of wind and of moisture readily explicable.

The above results regarding the influence of moisture and velocity of wind are precisely those which might rationally be expected on a little consideration of the subject. At first sight it might be supposed that all the constituents entering into the composition of atmospheric dust would be affected alike by alterations in the prevailing conditions of velocity of wind and of moisture. When, however, it is borne in mind that local conditions favouring or hindering the growth of fungi and similar organisms must determine the supply of cells derived from them, it becomes clear that velocity of wind *per se* can have no effect, and that moisture should tend rather to increase than to diminish their numbers, so long as it is associated with a suitable temperature. The amount of free inorganic particles and mere *débris* in any locality is dependent on conditions of dryness, and the extent to which they are raised into the atmosphere on conditions of velocity of wind; but the case is entirely different in regard to bodies, the supply of which is not regulated by mere mechanical conditions, but also by all the complex conditions affecting the growth and development of the organisms to which they belong.

Constituents most common and constant in atmospheric dust.

Proceeding next to a consideration of the special elements appearing as constituents in these preparations of atmospheric dust, it may be stated that those of most constant occurrence were the following:—particles of silica: amorphous granular masses: carbon: lime: starch corpuscles: cells, hairs and other fragments of vegetable tissues: fibres of cotton, &c: hairs and scales of insects: oil globules: pollen grains: spores and cells of fungi and algæ. Among the rarer constituents were *Acari*, specimens of which occurred in four preparations. They were more or less disintegrated in most cases, and did not appear to have entered the preparations in a living condition, so that they had probably really been introduced by the air and had not entered by creeping down the tube of the aeroscope. Distinct bacteria were observed in one or two instances only, and then in very small numbe"s, but all the preparations abounded more or less in minute monad-like molecules and globules of an undefined nature. Bodies which could be supposed to represent or belong to the higher infusoria hardly ever occurred, and no entirely unequivocal specimen was ever detected, as will be manifest on an examination of the plates.

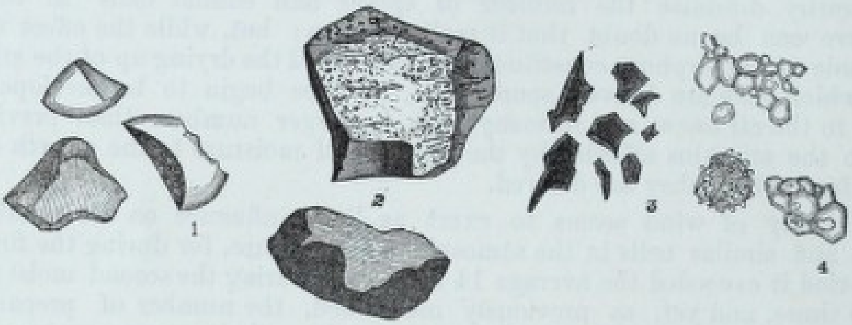


FIG. 2.—Inorganic elements in atmospheric dust: 1 and 2, silica, 3, carbon, 4, lime. Magnified 400 diameters.

Silica and amorphous particles.

The amount of silica and amorphous matter varied greatly in different instances, corresponding closely with the amount of coarse dust visible previous to microscopic examination. Carbon was rarely absent, and sometimes occurred in considerable amount, appearing either in the form of minute, angular fragments (*vide* Fig. 2) or of amorphous granules. Lime was present in many instances; sometimes in the form of granules, which were apparently formed of groups of fine needle-shaped crystals. These granules were of a pale yellowish colour, were sometimes collected into irregular masses (*vide* Fig. 2), and frequently formed an encrustation on the surface of fragments of silica from which they were separated by the addition of dilute-acids, which dissolved them with effervescence.

Starch and other vegetable debris.

Starch corpuscles occurred in all save five of the preparations, confirming Pouchet's observations regarding their constant presence in the neighbourhood of inhabited localities. In the majority of cases only one or two were detected, but in a few they were abundant. Wheat starch appeared to be the most prevalent form, but granules of rice were occasionally observed, and, in one or two instances, a few corpuscles seemingly belonging to some pulse, probably dhâl, were present. The fragments of vegetable *débris* were naturally very various, but, as a general rule, hairs and fragments of epidermis were most abundant. In some preparations collected during periods of violent wind, particles of woody tissue of considerable size occurred. Portions of cotton fibres were frequently observed, and particles of jute also were not uncommon. Hairs and scales of insects were present in many specimens, and in several cases were clearly traceable to the entrance of insects into the apparatus in order to deposit their ova in the anterior tube (*vide* Experiment II, Section III). In about one-half of the preparations, globules of various sizes, and apparently of an oily nature, were present. In those in which *Acari* also occurred they were peculiarly abundant, apparently due to their formation during the processes of decomposition taking place in the bodies of the animals.

Pollen.

Pollen grains were present in 52 of the 59 preparations, and in some were present in considerable numbers. Almost all the specimens observed are represented in the plates, and it will be seen that they belong to one or two forms only. The most abundant and constant of these were two varieties of circular cells, one distinguished from the other by the thickness and firm aspect of its coats, and both belonging to common species of grass (*vide* Fig. 3, 1 and 2).

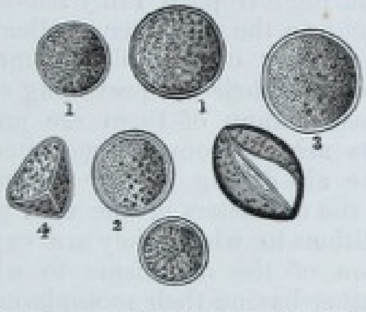


FIG. 3.—Pollen Grains: 1, Pollen of Ooloo Grass (Imperata Cylindrica): 2, Pollen of Doob Grass (Cynodon dactylon): 3, Pollen of another common grass: 4, Pollen of a Cyperus. Magnified 400 diameters.

A few specimens of the pollen grains of other grasses occurred, also a few resembling those of *Epilobium* (Plate I, Fig. 5), two apparently belonging to *Poinciana regia* (Plate V, Figs. 1 and 2,) and one seemingly of some liliaceous plant (Plate VII, Fig. 1). In the specimen collected on the 30th April a small mass of peculiar grains was present of a form only observed on one other occasion (*vide* page xxxiii). This is shown in the figure illustrating the specimen, under a power of about 120 diameters, with a portion of one of the grains under one of 400 (*vide* Plate IV, Fig. 4). The largest number of grains observed in any preparation was in that of the 28th March,—a dry dusty day. Forty-one specimens are figured in the corresponding illustration, but the number actually present was somewhat greater. They were much more abundant as a rule in the preparations belonging to the period from the 26th of February to the beginning of June than in those obtained during the rains, the average proportions for the two periods being as 3 to 1, and the actual excess in most of the specimens of the first period being very much greater than these numbers would indicate, as the average for the second was almost doubled by two days in the beginning of July, in which specimens abounded in the preparations. The preponderance in the former period is no doubt mainly to be ascribed to the fact that the grasses, which throughout were the constant and principal contributors, chiefly flower during that time, and also partially to the destructive effects of moisture on the pollen grains in the latter period. The observation of the presence of pollen grains in the air is one of long standing, but has acquired fresh importance of late in connection with Mr. Blackley's observations on their action in exciting Hay Asthma, and it is not devoid of interest to note their presence in the atmosphere of localities, such as Calcutta, in which the occurrence of the disease would not appear to have been generally noticed.

Spores, and similar cells.

Spores and similar cells were, as will be manifest on referring to the plates and tables, of constant occurrence, and were generally present in considerable numbers. The smallest number observed was 35, which occurred in the preparation of the 28th April belonging to the Presidency Jail, and in that of the 17th July of the Alipore series. In the latter instance the small number was manifestly greatly due to the circumstance that a spider or some small insect had spread a web of delicate threads across the pointed end of the funnel in the interior of the aeroscope. In 20 preparations the number was below 100, and in 19 it exceeded 200. In those cases where the numbers registered are low, they may be taken as absolutely representing all the bodies detected, but, on the other hand, where they are very high, they can only be considered to indicate that *at least* so many were present, as in such cases the whole of the bodies observed were frequently neither drawn nor counted. In some specimens, as for example that of Plate XI, Fig. 4, many of the cellules present may possibly have arisen due to processes of development occurring in atmospheric cells subsequent to their deposition, but in others, such as that of Plate XII, Fig. 2, the character of the majority of cells is not such as to warrant any such conclusion, and it is to be borne in mind that processes of growth and multiplication may probably take place to a considerable extent among such minute, delicate cells even while suspended in the atmosphere, when the latter provides such conditions of temperature and moisture as frequently occur during a tropical rainy season. If the presence of the delicate cellules so prevalent in the specimens collected during the rains were to be accounted for on the theory of their development in the preparations, it would be difficult to account for their not prevailing equally in those belonging to the hot and dry weather. Many of them are probably sporidia produced by the mycelial filaments arising from the germination of the large septate spores so abundant in the air during the dry season, and it is interesting to observe the adaptation in the characters of the cells prevailing at different seasons to the external conditions to which they are exposed, so as to secure the diffusion and reproduction of the organisms to which they belong; those abounding in the dry weather having their protoplasm protected by thick resistant coverings, and those present in the moist air of the rains being so frequently of such extreme delicacy. That the majority of the cells were living and ready to undergo development on meeting with suitable conditions was very manifest, as in those cases in which preparations were retained under observation for any length of time, germination rapidly took place in many of the cells. In few instances did any development take place beyond the formation of networks of mycelium or masses of toruloid cells, but in one or two, distinct sporidia were developed on the filaments arising from some of the larger septate spores, and in a few others, *Penicillium* and *Aspergillus* produced their characteristic heads of fructification. Some of the sporidia closely resembled in characters the peculiar curved cells so abundant in the specimens of June 12th and 30th (Plates VIII & IX, Figs. 2 and 1), whilst others were narrower, more crescentic, and traversed by two or three septa.

Nature of the cells present.

With regard to the precise nature of the spores and other cells present in various instances little can be said, as, unless their development were to be carefully followed out through all its stages, it is impossible to refer them to their correct species or even genera. This, however, is a matter of comparatively little importance from the point of view with which the present observations were undertaken, more especially when it is taken into consideration how extremely uncertain and ill-defined the relations which many of these bodies bear to one another is at the present time. The greater number of them are apparently referable to the old orders of fungi Sphæronemei, Melanconei, Torulacei, Dematici, and Mucedenes, while some probably belonged to the Pucciniæi and Ceomacei. Among those belonging to the Torulacei the most interesting was a representative of the rare genus Tetraploa (Plate V, Figs. 3 and 4, VI, Fig. 2, IX, Fig. 2). Distinct green algoid cells occurred in some specimens, especially in that of the 17th April. This was obtained from Alipore, and contained an abundance of green, circular cells of various sizes, many of them showing a distinct division of their contents into from two to four separate masses. They occurred both in small aggregations and scattered singly throughout the preparation, and their presence in such numbers was probably connected with the fact that the tank in the immediate vicinity of the aeroscope was being emptied at the time, preparatory to being subjected to a process of cleaning. The numbers of different kinds of cells present in different preparations did not vary greatly; as an average about 18 were present, while in some cases as many as 30 and in others as few as 10 or 12 were observed.

In proceeding finally to consider the results of these observations as bearing on the question of the existence of any connection between the presence of any peculiarities either in quantity or kind of atmospheric particles with the prevalence of special forms of disease, a few words are necessary in explanation of the tables containing the statistics of disease (*vide* page xxii—xxv.) It will be seen that five diseases only are referred to, namely, diarrhœa, dysentery, cholera, ague, and dengue. These were selected on account of the fact that they may all be supposed to be capable of being induced by atmospheric causes. Four of them were, moreover, among the most prevalent forms of disease during the period of observation, and although this cannot be said of

Prevalence of five special diseases compared with presence of spores and cells in the atmosphere.

the fifth—cholera, which certainly was not very prevalent in either locality, and in Alipore occurred in such isolated cases as to afford little or no ground for comparison—the figures regarding it are entered because the observations were originally undertaken with special reference to it, and also because a distinct period of prevalence occurred in the Presidency Jail at a time when the other locality was exempt.

Explanation of statistics relative to these diseases.

It is unfortunately impossible to determine how long after their appearance in the air special atmospheric particles might exert an influence in inducing disease, but with a view of, as much as possible, facilitating the detection of any such influence, the statistics of four different periods are given in connection with each observation. The first of these comprises the three days previous to an observation, the second the day itself, the third the three following days, and the fourth the entire week made up by the three previous periods and of which the day of observation formed the centre. For each of these the actual population of the jails and statistics of the various diseases are given, so that they can be compared with the figures showing the numbers of spores and other cells collected from the atmosphere on the various dates of observation. The figures of population consist merely of the sums of the figures entered in the daily Lock-up registers, and no attempt has been made to reduce them to averages, or to state the figures of the diseases in percentages, as this would have rendered the tables more complicated, and the figures, as they stand, appear to fulfil the requirements of the case sufficiently well. A glance at the tables will show that, for all practical purposes, the influence of the fluctuations in the actual population on the prevalence of the diseases under consideration may be neglected, which is all that is required to clear the way for the consideration of the facts regarding the atmospheric spores and cells.

Explanation of diagrams of disease.

The first and most general point of enquiry regarding these is, whether the presence of large numbers of them in the air appears in any respect connected with the prevalence of any of the diseases. Two diagrams (II and IV) have been constructed in order to elucidate this point. These show the fluctuations in the numbers of spores and cells at the various periods of observation, and the contemporaneous fluctuations in the prevalence of the diseases, by a series of graduated lines. It will be seen that each diagram contains a column at the left hand showing the number of graduations from below upwards, while the numbers of the observations are shown at the top. The number of each graduation corresponds with the actual number of cases of disease for each period and with the number of the spores and cells reckoned by tens: thus when the line corresponding with any disease reaches into the twentieth graduation, it indicates the occurrence of twenty cases of that disease; but when the line indicative of the number of spores and cells reaches the same height, it represents the presence of any number of these bodies from two hundred to two hundred and nine, inclusive. The figures of disease consist of the sum of those for the day of observation and the three following days, so that if any appreciable effect were produced during that period, it ought to be traceable by means of the angles formed by the two lines. As mentioned previously, this is at best but a very imperfect attempt at attaining the desired information, for from the absence of daily registrations, the data are necessarily imperfect, so that even were effects apparently traceable in any instance, the possibility would yet remain that the connection was merely apparent and the phenomenon accidental. Moreover, a connection might really exist and yet not appear if the curves of disease were dependent on the conditions of days other than those of observation; still the comparison, such as it is, has been made with the view of ascertaining whether the results in any instance furnish any grounds for expending time in more elaborate observations in the same direction. When these diagrams are examined, it certainly appears that no connection is traceable between the two phenomena. The rises and falls in the prevalence of the diseases in no instance show any constant coincidence either of agreement or discord with those in the numbers of atmospheric cells, and as the numbers of the latter have been already shown to vary independently of varying conditions in velocity of wind, the conclusion, so far as the information

No connection traceable between numbers of atmospheric cells and prevalence of any of the selected diseases:

goes, is that mere number of recognisable atmospheric cells in a given bulk of air has no effect on the occurrence of the diseases under consideration, and is not even capable of indicating the existence of conditions favouring their occurrence.

Nor between special forms of cells and such prevalence.

The next point to be considered is, whether the presence or prevalence of any special form of cell appears to be capable of acting in either of these ways. The only instance which in the least suggests the existence of such a capability is in reference to cholera; for if we compare Fig. 2, Plate VIII, illustrative of the bodies present in the specimen obtained at Alipore on the 12th June, with Fig. 1, Plate IX, showing those in that of the 30th June at the Presidency Jail, the comparatively large numbers of peculiar curved spores or sporidia in both cannot escape notice, and the figures of cholera for the weeks to which the observations belong are three and five respectively. Moreover, these cells did not begin to appear in any numbers in the specimen obtained in the Presidency Jail on the 16th of June, that is, in the specimen of the entire series next in date to that of the 12th June, but only in the one of the 23rd, so that a distinct interval elapsed between their appearance in the two localities, and their appearance in both coincided with the occurrence of cases of cholera in them. When, however, we come to compare the subsequent specimens in both the coincidence ceases, for, on examining those of the 20th and 26th June and 3rd July at Alipore, and those of the 7th, 12th, and 21st July at the Presidency Jail, it will be seen that the numbers of the peculiar cells present in them did not greatly differ, whilst the disease ceased abruptly at Alipore, but continued for two weeks in the Presidency Jail. That the coincidence was a purely accidental one, was, moreover, rendered evident by the result of some further observations (Section III, Experiments II, III, and IV) conducted in the Presidency Jail during a period in which cases of cholera occurred at another time of year; for in these instances bodies of a like nature were absent, and the cells present were merely those normal to the time of year. This affords an excellent example of the benefits to be derived from continuous observations in one locality in place of isolated ones confined to periods of prevalence of disease in several. Had the latter alone been carried out, the deceptive coincidences pointed out above might easily have been overlooked, and the observation of the presence of these cells have acquired undue importance.

Results of this series of experiments.

The principal results obtained from this series of observations were the following :—

1.—Distinct infusorial animalcules: their germs and ova are almost entirely absent from the air in Calcutta and the neighbourhood.

2.—Bacteria are hardly ever to be detected in it, but there is constantly present a large quantity of molecular matter, and the possibility remains that much of it may be of a bacterial nature.

3.—Spores and other vegetable cells are constantly present in the air in considerable numbers; the majority of them are alive and capable of growth and multiplication; their numbers are independent of velocity and direction of wind; and they are not diminished by moisture.

4.—No connection could be traced between the numbers of cells present and the prevalence of diarrhœa, dysentery, cholera, ague, or dengue; nor between the presence of any special form and such prevalence.

5.—The amount of the amorphous and inorganic constituents of atmospheric dust is directly dependent on conditions of moisture and of velocity of wind.

SECTION III.

MISCELLANEOUS AEROSCOPIC OBSERVATIONS.

In addition to the regular series of observations detailed in the preceding section, various other experiments were tried by means of the aeroscope in the same localities. The majority of them were made, previous to the others, during the months of December 1871 and January and February 1872, but a few were also carried out in March 1873, in connection with the occurrence of some cases of cholera in the Presidency Jail at that time. Only a few of them demand any special mention, while the results of the remainder may be briefly summarized. The inorganic and amorphous constituents need not be alluded to, as they presented the ordinary features common to all specimens of atmospheric dust, the relative proportions of the various elements merely varying in some degree. Starch corpuscles, hairs and other fragments of vegetable tissues, with fibres of various kinds, were present in small quantities. Pollen grains, as a rule, were almost or entirely absent, but one specimen contained a form only observed on one other occasion, and that at a different place after some months' interval (*vide* Plate IV, fig. 4). In every case spores and fungal cells were present, and generally present in considerable quantities. The forms differed little from those occurring later, and figured in the plates illustrative of the previous section, but, as a rule, septate spores and sporangia were not so abundant as in these, whilst small oval and fusiform cells of an olive-greenish hue were present in larger proportion. These preparations also contained no bodies recognisable as dried infusoria or the cysts or ova of such organisms.

Times when observations were carried on and their general results.

The total number of experiments amounted to 28; and the sites chosen for observations were roofs of various elevations, posts like those afterwards employed in the systematic observations, the branches of trees, &c. When used in irregular situations, the apparatus was fitted to a spindle surmounting a metal rod about 5 inches in height with a heavy circular base which kept it in position. The shortness of the support, though very useful in allowing of easy transport and adaptation to comparatively confined spaces, had no doubt the disadvantage of not raising the mouth of the tube so high as to avoid particles of various kinds blown from surrounding surfaces, but not belonging in reality to the class of bodies forming the subject of this report—the suspended impurities of the air.

Number of experiments, and localities in which they were tried.

I shall now detail the results of one or two of the experiments which seem to involve points of some interest.

Experiment I.—The apparatus was set on an old masonry pillar, originally forming one side of a gateway, in the garden at the Presidency Jail. It was exposed from 9-30 A. M. of the 10th to 8 A. M. of the 11th January 1872. The slide showed some dust visible to the naked eye. On microscopical examination it was found to contain the usual inorganic and amorphous constituents, but was chiefly characterised by the presence of an extreme profusion of minute pale-green cellules. They showed various stages of development, some being circular, others oval, and others again distinctly bi-lobed and evidently proceeding towards complete division. They were universally diffused over the preparation, but were specially abundant in the neighbourhood of one or two masses of the brownish filaments of a large *Lyngbya* which were present. Very few other kinds of cells were observed. This specimen was instructive in showing the necessity for great caution in assuming the general diffusion of large numbers of peculiar cells in the air of any locality merely because of their abundance in specimens collected there. Had the algoid filaments, entangling masses of the cellules in this case, not been observed, it might have been very naturally concluded that the latter were generally diffused through the air to which the apparatus was exposed, but, taking all the circumstances into consideration, the probabilities were greatly

Specimen abounding in greenish cellules.

in favour of this not being the case, and of their preponderance being really due to their having been introduced in one or two aggregations and subsequently diffused over the surface of the glass.

The three following experiments were those previously alluded to as having been carried out during the course of a period in which cases of cholera occurred within the Presidency Jail.

Experiment II.—A mild case of cholera having occurred during the night between the 15th and 16th March 1873, the aeroscope was placed on the post within the jail, in the same locality as in the systematic observations, at 8 A. M. of the 16th and remained exposed until 1 P. M. of the 18th. The specimen showed a considerable amount of fine dust visible to the naked eye. This, as usual, was found to consist mainly of amorphous fragments with a sprinkling of angular particles of silica and a few masses of carbon. The vegetable cells present were in relatively small proportion, and consisted of pollen grains with fungal cells and spores, like those occurring in the specimens collected at a similar period of the previous year and figured in Plate I. The olive-green, oval and sometimes somewhat truncate and angular cellules present at that time re-appeared here, and there was an absence of any of the forms which appeared in any degree specially to characterise the air during the prevalence of cholera in the preceding July.

Similar organisms present at corresponding seasons of 1872-73.

Elongated hairs, which had frequently been observed in other specimens at various times of year, were present in considerable abundance, and their nature and origin were here detected, for, on examining the felt-like covering investing a collection of ova which had been deposited by some insect within the anterior part of the apparatus, it was found to consist of a mass of such bodies densely interwoven. The hairs in question are of a greyish-green tint, pointed at either extremity, and enclose a mass of beautifully striated ova.

Experiment III.—Two fatal cases of cholera occurred in the jail on the 22nd March, a 3rd on the 23rd, and a 4th on the 25th. The aeroscope was set as usual at 10 A. M. on the 22nd and remained exposed until 11 A. M. on the 24th. The preparation contained a good deal of visible dust. On microscopical examination an abundance of the spores, normal to the time of year, were detected with a profusion of fine molecules and granules. One example of a spore of the *Tetraploa* occurring in several specimens of the previous year *(vide* Plate IX, fig. 2, &c.), and numerous specimens of brown septate filaments containing masses of greenish protoplasm, were observed. A very large proportion of the spores and even some of the filaments above alluded to, germinated rapidly, the protoplasmic masses in the latter giving origin to delicate greenish filaments, more especially in those cases in which they were contained in joints which were open at one or both extremities due to rupture of the filament to which they belonged.

Specimen with abundant germinating spores.

Experiment IV.—The aeroscope was set as usual at 11 A. M. of the 24th March and remained exposed until 7 A. M. on the 29th. Several cases of cholera occurred during the interval. The preparation contained a large quantity of dust visible to the naked eye. The microscope showed a profusion of brownish amorphous masses, numerous angular particles of silica, and an infinite number of minute molecules and granules. Hairs like those described in Experiment II abounded, and a few insect scales were likewise present. There were also large quantities of wheat starch together with a certain proportion of smaller grains apparently belonging to rice. The proportion of spores and pollen grains present was considerable, but they presented no special peculiarity, nor did any form greatly preponderate. One specimen of the peculiar small dark-brown cells, aggregated in fours within a delicate envelope and figured on page xxxv, and one large oval cell with firm walls and mulberry-contents, apparently an ovum of some kind, were also present.

Specimen containing an ovum.

The latter three experiments were useful in affording an opportunity of comparing the microscopic characters of the air in a locality at two different times of year, in both of which cases of cholera occurred. The results of this comparison in the present instance showed no special correspondence between the nature of the bodies present and no preponderance of any individual form on both occasions; on the contrary, there was a perceptible difference in them apparently due to seasonal influences. It is possible that among the heterogeneous mass of bodies included, in default of a better term, under the word molecules, there may be various species possessed of various distinct properties, and that some such species may have been present on both occasions, but in so far as bodies presenting recognisable characteristics are concerned, the present set of experiments did not even go so far as to indicate the presence of any general atmospheric condition coincident with the occurrence of cholera, far less did it tend to connect any special atmospheric organism with the disease.

No special characteristics in specimens obtained during the occurrence of cholera.

A certain number of specimens were collected specially with the view of ascertaining whether bodies definitely recognisable as bacteria occurred constantly or frequently in the air. The period during which they were obtained was early in the rains, when the air and ground were both moist, so as to avoid as much as possible an excess of the coarser inorganic constituents of dust. The preparations were carefully examined under a power of 1,000 diameters, but although minute rounded monad-like particles were constantly present in large numbers, and a few more elongated stave-like bodies were occasionally to be detected, distinct unequivocal bacteria were of very rare occurrence. The three following instances may be cited as illustrative of such experiments:—

Search for bacteria in atmospheric dust.

FIG. 4.—Cells and bacteroid particles of atmospheric dust. Magnified 1,000 diameters.

Experiment V.—(Fig. 4). The aeroscope was exposed for 24 hours of showery weather on the post in the Presidency Jail. The preparation contained hardly any trace of dust visible to the unaided eye. Some spores and other fungoid cells were present, among which was one specimen of a peculiar compound body, previously observed on several other occasions, consisting of four dark brown, oval, slightly constricted cells, adherent in pairs and included within a very delicate enveloping sac, invisible save under a very high power. There was also an evenly diffused sprinkling of very minute rounded oval and irregular particles and a very few bacteroid bodies.

Abundance of minute molecules.

Experiment VI.—(Fig. 5 a.) The aeroscope was exposed for 24 hours in the Presidency Jail. During the greater portion of the time, the weather was still and close, and at one period a heavy fall of rain occurred. As in the previous experiment hardly any coarse dust was present. The preparation contained a sprinkling of minute amorphous fragments and fungoid cells, many of the latter being evidently spores of *Aspergillus*. No unequivocal bacteria could be detected, but one or two rod-like bodies were present, and minute micrococcoid particles were generally diffused over the entire surface.

Absence of distinct bacteria.

FIG. 5.—Bacteroid particles, spores of *Aspergillus, &c.* Magnified 1,000 diameters.

Experiment VII.—(Fig. 5 b.). Another preparation was obtained from the same locality as the two previous ones. Here also there was an almost entire absence of particles visible to the naked eye. It contained a few of the common amorphous and carbonaceous bodies, and one or two minute fragments of silica. Various kinds of cells were present, including a good many spores of *Aspergillus*, one specimen of a curious *Spirillum* of considerable size, and greenish colour, and one of the compound bodies described and figured in Experiment V. No distinct bacteria could be detected, but one or two small staves were observed together with a generally diffused sprinkling of granules and micrococcoid particles.

Numerous spores of Aspergillus.

In these and similar observations, although there was a general absence of distinct bacteria, there was, as is almost invariably the case in all specimens of atmospheric dust, a general diffusion of minute particles resembling those included by Robin under the term micrococcus, and as long as the precise nature of all these bodies remains undetermined, it is impossible to deny that many of them may be of a bacterial nature, and capable of growth and multiplication on coming in contact with a favourable medium.

Nature of the molecular matter uncertain.

SECTION IV.

OBSERVATIONS ON DUST DEPOSITED ON LEDGES, LEAVES OF TREES, &c.

Some observations of this kind were made at different times. The specimens were obtained by lightly brushing the surface bearing the dust with a clean camel's hair pencil which had been moistened by immersion in boiling distilled water. However light the friction may be, it is impossible in this way to procure specimens accurately representing atmospheric dust, as organisms growing on the surface under examination are almost certain to be detached and appear in numbers very much greater than they are in the dust diffused through the air. Some of the specimens of this series showed this very distinctly, the washings from the leaves of a *Dracæna* constantly containing a profusion of delicate bluish-green cells and filaments which did not prevail in specimens of dust collected from the air in the immediate neighbourhood, while those collected from the upper surface of the leaves of a *Ficus* showed only a very few specimens of bright-green circular palmelloid cells which were present in very large numbers in those from the lower surface of the same leaves.

Fallacies inherent in such observations.

The proportions of the various constituents of the dust naturally varied considerably with the locality from which the specimens were obtained. When the latter were derived from the leaves of trees near roads traversed by considerable traffic, the sand and other inorganic constituents were present in large amount, whilst in those from trees situated in wide open areas covered with grass, the inorganic elements fell to a minimum, whilst spores, filaments, and algoid cells were present in relative and sometimes in absolute abundance. The proximity of tanks also in some cases appeared partially to influence the characters of the specimens, as, in those obtained from trees growing just at the edge of the water, fragments of distinct confervoid filaments and bright-green algoid cells were present in much greater abundance than in others from surfaces far removed from bodies of water. The dust collected from the ledges of doors, windows, and other places within houses usually contained a large amount of silicious particles, and comparatively few of the larger septate spores so common in the outside air, but abounded in minute greenish, rounded and oval cells, evidently the spores of *Penicillium* and *Aspergillus*, dried stems and heads of the latter fungus being also occasionally present in addition to the spores. Specimens from the rough surface presented by the broken glass covering the wall of the Presidency Jail contained, among other inorganic constituents, numerous sharp angular green particles of glass and an abundance of carbon. Starch corpuscles and fragments of the coats of wheat grains were also present in peculiar abundance in them,

Circumstances influencing the characters of dust.

and, with the carbon, were probably due to the proximity of one of the bake-houses of the jail.

Constant presence of spores and absence of infusorial animalcules.

All the specimens examined contained spores and other vegetable cells in some, and generally in considerable numbers, but only in two cases were any bodies present which could be supposed to be the cysts of infusoria. Entire dried infusoria were never observed, and even the cysts alluded to above were of a very doubtful nature, all that could be said regarding them being that the possibility of their infusorial nature was not precluded. Hardly any pollen grains were present in any instance, a fact no doubt due to the grasses not generally being in flower at the time of year (November and December) when the observations were carried on.

Specimens of dust from cholera localities.

Two specimens of dust obtained from localities in which cholera was prevailing may be described somewhat more fully here. The first of these was washed from the leaves of a shrub in a Bengali village in which cholera was prevailing severely, several houses containing cases of cholera at the time being in the immediate neighbourhood. It contained the normal constituents of atmospheric dust, inorganic and organic particles, large septate spores, &c., and was chiefly characterised by a profusion of minute colourless curved cells, with a sprinkling of somewhat clavate jointed filaments and colourless circular cells. The second specimen was obtained from the leaves of a bamboo close to a house in another village in which cholera was present. It consisted mainly of angular particles of silica together with a sprinkling of the pollen grains and spores present in common specimens of air. No specially characteristic form could be detected in it.

Before concluding this section a brief account may be given of one or two experiments which were tried regarding the results of adding dry dust to putrescible solutions.

Experiments on fermentive properties of dust.

Experiment I.—On the 15th April 1873, two wax cells were very carefully prepared. A drop of fresh urine which had just been subjected to prolonged boiling was placed on the centre of the cover glass of each by means of a glass rod which had been heated to redness immediately previous. The drop placed on the first cover consisted of pure urine, but that on the second contained a little dry dust obtained by applying the moist end of the rod to a ledge about 7 feet from the floor on a glass door opening into a south verandah. That the dust had been undisturbed for some time was evident from the state of the surface on which it lay, and that it was dry, may be judged from the fact that during the previous week the lowest maximum reading of the thermometer registered in Calcutta at the Office of the Surveyor General was 90° F., whilst the maxima for the four previous days had been 99°, 101°9, 103°5, 102°0 with contemporaneous mean humidities of ·73, ·69, ·59, ·68 and no rain for above a month previous. The verandah on which the door in question opened is, moreover, exposed to a hot dry blast from the heated roofs of a range of low buildings, whenever the direction of the wind is from the south or south-west, as it had been almost without intermission for seven days before.

Rapid development of fungi and bacteria.

Both preparations were then sealed and kept under observation. That consisting of the pure urine remained perfectly clear, and, up to the present date, (September 9th) has never showed anything save a few crystals and amorphous bodies. The preparation inoculated with the dust, on the second day, contained a sprinkling of very active bacteria, and on the following one was distinctly cloudy to the naked eye and crowded with similar bodies. Some of the spores contained in the dust had also by this time germinated and their mycelium spread rapidly, absorbing the fluid and almost entirely drying up the preparation within a week.

Experiment II.—The aeroscope was carefully washed with strong spirit and subsequently heated by moistening it with more spirit and burning off the latter. A large clean glass cover which had been passed through the flame of a spirit-lamp, was then put into it and the surface moistened with some fresh urine which had just been subjected to prolonged boiling. The apparatus was next set on the post in the Presidency Jail, and remained exposed for 21 hours, being removed on the morning of the 21st April. A violent storm of wind, dust, and rain occurred during the period of exposure, and the preparation was found to contain a large amount of dust visible to the naked eye. The glass was carefully removed by means of a pair of forceps which had been exposed to a red heat,* a little freshly boiled urine was added to the dust, and the cover was then applied to a wax cell. Finally a drop of the same urine was mounted in a second wax cell, and both preparations were set aside. The experience of the previous experiment was repeated in this, for, while the preparation containing the dust rapidly showed the presence of bacteria and fungal mycelium, that composed of pure urine remains unchanged until now. The proportion of active bacteria was not so great and that of mycelium was very much greater in the dust preparation of this experiment than in that of the former one. Some of the mycelial filaments gave origin to lateral twigs bearing secondary spores or sporidia not very unlike those occurring in such abundance in the specimens of atmospheric dust figured on Plate VIII, fig. 2, and Plate IX, fig. 1.

Dust collected during a dust-storm.

Experiment III.—Two wax cells were prepared as usual, a drop of pure freshly boiled urine set in one of them, and a drop of the same urine, to which a little dry dust obtained from a window ledge six feet from the ground had been added, in the other. The lowest maximum temperature registered for the week was 84°2, and the maxima of the three previous days had been 93°0, 92°0, and 84°2. The mean humidity of the air for the same days was ·79, ·81, ·80, and there had been a fall of 2·19 inches of rain during the previous month. Two days afterwards the second preparation was cloudy to the unaided eye, and on microscopic examination was found to be crowded with active bacteria, whilst the first remained perfectly clear and free of bacteria and fungi until, due to a slight separation of the wax from the slide, the cell ceased to be air tight and the fluid evaporated, an accident which occurred six days after the commencement of the experiment.

Results in inoculated and pure specimens of urine.

The two most interesting points in connection with this series of observations are, 1st, the almost entire, if not entire, absence of infusoria, their cysts or ova from the dust collected in various localities, such as the leaves of trees, &c., in which they have been described as occurring in abundance; and, 2nd, the remarkable effects in the way of development of bacteria following the addition of dry dust which had been exposed to a tropical climate at the hottest and driest time of year. The dryness no doubt is only a very relative matter in Calcutta, but yet at the very time that the dust was capable of producing these remarkable effects, the air was dry enough to cause the leaves of most garden shrubs to lose their freshness and acquire a semi-withered aspect. It must, however, be borne in mind that as the samples of dust were obtained from exposed situations, they may have contained specimens of bacteria or of their germs which had not been subject to drying for any length of time as any insect is capable of transferring many such bodies from a fluid or a damp place to a collection of dry dust.

Chief points of interest in these observations.

SECTION V.

OBSERVATIONS ON THE DUST DEPOSITED DURING LIMITED PERIODS ON MOIST GLASS SLIDES.

Only a few such observations were carried out, as it was found that the specimens so obtained were peculiarly liable to contamination from bodies not really of an atmospheric nature. It is almost impossible to expose surfaces

* The forceps, glass rods, &c., employed were always carefully heated in the flame of a spirit-lamp before being used.

of glass to the air for any length of time in such a way as to allow of the deposition of suspended particles upon them, and at the same time to prevent the likelihood of birds or insects adding accidental impurities to them, quite independent of those generally diffused through the air. Even aeroscopic preparations, as has been already pointed out, are liable to be affected by the entrance of insects into the tube, and it is clear that a flat surface of glass exposed to the air without any cover is very much more so. Birds can be kept off by means of enclosing the slides within a light cage, but any cage securing the exclusion of insects would at the same time very seriously interfere with the access of the bodies held in suspension in the air.

Difficulties in securing good specimens of dust by deposition.

The localities in which experiments were tried were, 1st, the flat roof of a building 40 feet from the ground; 2nd, the roof of another building 15 feet from the ground; 3rd, the surface of the ground in a garden full of shrubs and small trees; 4th, one of the wards in the Presidency Jail. The preparations from the first locality were obtained by exposing slips of glass for periods of 12 and 14 hours during the night in the months of November and December. Four slips were employed on each occasion, their surfaces being coated with strong glycerine, and a certain amount of protection being afforded to them by means of a cage-cover. All the specimens very closely resembled one another in their characters, containing a very scanty sprinkling of silicious and amorphous particles, one or two large septate spores and a few sporules of *Aspergillus*. In two not merely the latter, but entire stems and heads of the fungus were present. Preparations from the lower roof were obtained on three separate occasions in November, January, and February. Four slides were employed on each occasion, and the length of exposure was about 12 hours in two instances, and 72 in the third. The preparations obtained by the short exposures were alike in containing very little dust of any kind, and a scanty sprinkling of spores and fungoid cells. The third set of preparations contained an abundance of dust, visible to the naked eye, and on microscopical examination found to consist of the usual silicious and amorphous particles, with numerous masses of granular carbon, a large quantity of wheat starch and some filaments of cotton. There was also a sprinkling of angular fragments of green glass and a certain number of fungal cells, the majority large septate sporangia, the protoplastic masses contained within them having in many instances begun to emit mycelial filaments. The specimens obtained at the surface of the ground were the result of one exposure of 13 hours during a night in November. They were four in number and contained very little dust of any kind. Very few spores or cells were present, the only form observed in any numbers being an oval colourless spore of considerable size apparently belonging to some Agaric. Twenty of these bodies were observed, and it may be remarked that this and one or two of the slides of the series described immediately above were the only preparations in which they occurred.

Localities in which experiments were tried.

Only two sets of experiments were tried in the last locality, the ward in the jail, as the amount of dust deposited in them was found to be so great as to render the preparations very obscure. In the first instance four slides prepared with glycerine and placed on a small wooden stage were introduced into a ward, containing 25 men, and were allowed to remain exposed for 14½ hours, not being removed until the prisoners had left the place on the following morning. All of them were thickly coated with dust consisting of silicious and amorphous particles, with an abundance of epithelial scales, starch corpuscles, and fibres derived from the clothing and blankets of the prisoners. Thorough examination was impossible due to the thickness of the dust, but the proportion of spores or other fungal cells present was certainly relatively very small. A few pollen grains and one body resembling a *Peridinium* were detected. In the second experiment the slides were only allowed to remain exposed for 8 hours, being introduced some time after the men had been locked up, and removed before they came out on the following morning. The preparations were much less loaded with dust than in the previous instance. They contained an abundance of particles of silica and of amorphous matter in brownish masses of various sizes. All throughout there was

Specimens obtained from wards in the Presidency Jail.

a profusion of granular and molecular matter. Numerous epithelial scales, with a few oil globules, fibres of various kinds and fragments of hairs, were also present. Only a few spores and other fungal cells were detected, and these showed no peculiarities, being of the ordinary forms observed in the external air. Only a very few cellules resembling *Aspergillus* spores were found.

This set of experiments confirmed the fact of the general diffusion of fungal elements in the atmosphere, with an almost absolute absence of infusorial cells. The relatively small proportion of fungal cells present is just what might be expected from the method of collection employed, as where gravitation alone comes into play the heavier inorganic and amorphous suspended particles must almost inevitably appear in high proportion.

SECTION VI.

OBSERVATIONS ON ORGANISMS AND OTHER SOLID BODIES CONTAINED IN DEW.

Few experiments and unsatisfactory results.

Only four experiments of this kind were tried, as the results obtained by their means were unsatisfactory, and presented nothing remarkable or worthy of special investigation :—

Apparatus employed to collect the dew.

Experiment I.—A clean test tube was taken, and a small glass funnel having been fitted to it (the nozzle having been passed through a tight-fitting clean cork in the mouth), it was placed in a porous earthenware vessel. The lower part of the vessel beneath the tube was occupied by straw, to allow of the easy draining off of fluid, while the rest of it was filled with broken ice to facilitate condensation. The apparatus was then set on the ground in the garden of the Presidency Jail at 8 P. M. of the 5th December 1871, and allowed to remain until 6-30 A. M. of the 6th. About half a drachm of fluid was found in the test tube. The night was cold and still, and the morning very misty.

Several preparations were examined, but hardly anything could be detected in them. A few minute fragments of silica, a very scanty sprinkling of fine molecules and granules, some bodies resembling minute, still bacteria, and one or two fungoid cells of various kinds were present.

Specimen in which a small diatom was present.

Experiment II.—The same apparatus was set in the same place at 10 P. M., 6th December, and removed at 6-30 A. M. of the 7th. Specimens of the moisture adhering to the sides of the funnel were first examined. They contained a very scanty sprinkling of silicious particles, a few molecules and granules, and one or two spores and sporoid cells of kinds prevailing in specimens of atmospheric dust collected at the same time of year. There was only about half the amount of fluid in the tube this time, as compared with the former one; but it contained a visible sediment, consisting of angular fragments of silica, and an abundance of particles of various sizes. A few fragments of brown septate mycelial filaments, one or two spores and a single specimen of a small species of diatom were also present.

Second method of collection.

Experiment III.—A different apparatus was employed in this case, consisting of a clean glass basin, surrounded by ice and straw, in a larger unglazed earthenware vessel. This was set in an open space, in the same garden as before, at 8 P. M. of the 8th December and remained until 6-30 A. M. of the 9th. A considerable amount of fluid had collected during the interval and was found to contain a scanty sprinkling of fungal cells and greenish filaments.

Experiment IV.—The apparatus employed in the previous experiment was set again in the same place at 8 P. M. of the 11th December and remained exposed until 6-30 A. M. of the 12th. The night was still, cold and tolerably free from mist. A considerable quantity of dew was present on removal. It contained a few silicious and amorphous particles, a good deal of fine molecular matter, and some spores and fungoid cells of several kinds.

All the specimens obtained agreed with one another very closely in the characters of the bodies which they contained. It was impossible by their means to form any approximate idea of the number of spores and other cells generally diffused in the air, as, unless in the case of bodies sinking down so as to form a recognisable sediment, large numbers of cells might be present in the fluid and yet not appear in any considerable numbers in the specimens of it which were examined; whilst, on the other hand, an opposite error might arise from the latter containing numerous cells derived from masses, only one or two of which were present. The only remarkable feature in any of the preparations was the occurrence of a diatom in No. II, as this was the only occasion on which such a body was observed in any of the observations on atmospheric dust.

General uniformity in characters of specimens.

SECTION VII.

OBSERVATIONS ON ORGANISMS IN RAIN-WATER.

The question of the existence of Bacteria in atmospheric air and of their diffusion by its means is one of great interest and importance, and is, moreover, one regarding which there is considerable difference of opinion. Formerly their presence was denied only by the supporters of spontaneous generation, but in more recent times various observers have appeared, who, while denying the origin of bacteria *de novo*, regard their presence in the air as quite exceptional and ascribe their rapid appearance in putrescible solutions, not to the entrance of atmospheric germs, but to the occurrence of contact inoculation. Any careful observations bearing on the point are, therefore, a desideratum, and I have accordingly no hesitation in introducing a somewhat detailed account of some here.

Question of existence of Bacteria in air.

The water collected during heavy tropical showers furnishes a good subject for such investigations, as it is likely to contain specimens of the solid particles contained in the atmosphere washed down by the rain in its descent; affords a medium in which they can develope, to some extent at all events, and is, moreover, one in which, with due precautions, risks of contact communication can be reduced to a minimum. The following series of observations were therefore made on it during the present summer:—

Experiments regarding their presence in rain-water.

Experiment I.—A clean glass basin was carefully washed both internally and externally with spirits of wine. Some more spirit was then put into it, ignited and allowed to burn off. The basin was next placed on a roof about 40 feet from the ground, being raised over a foot from the flat surface in order to diminish the risks of water splashing up into it. A heavy shower had fallen about half an hour before and another was just beginning when it was exposed. It was allowed to remain for three hours, and when removed contained about three drachms of clear fluid. Two specimens were taken from it by means of a pipette which had been heated to redness immediately previous, and it was then set in a glass saucer and covered by a bell-glass. Both saucer and bell-glass had been washed with spirit and fired, and the edges of the latter had been coated with wax heated to 240° F., so that, when it was pressed down on the saucer, it isolated the basin in a hermetically sealed chamber. The specimens removed before this was done contained a few small amorphous brownish masses, particles of silica and minute molecules like those normally occurring in atmospheric dust, together with one or two small greenish cellules apparently spores of *Aspergillus*. The basin remained untouched beneath the bell-glass for four days. The water remained perfectly clear, but two days after its collection a few delicate whitish flocculi appeared floating in it and gradually increased in size and number. Specimens of both fluid and flocculi were carefully removed by means of a pipette which had, as before, been heated to redness. The flocculi consisted of mycelial filaments of various kinds, some of which bore penicilloid heads with young spores on lateral branches, while others took their origin from large septate spores like those

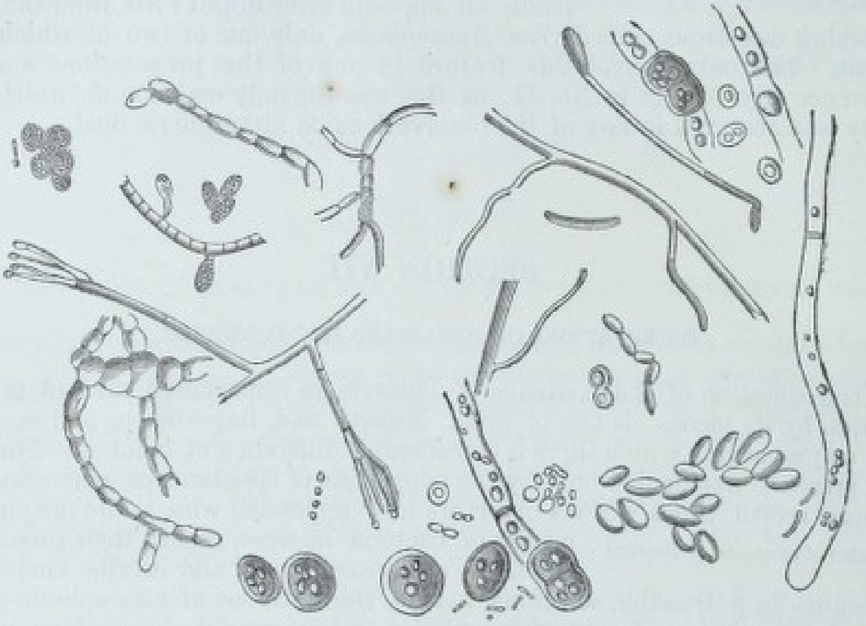
Means of obtaining and preserving specimens.

Appearance of flocculi in the fluid.

commonly present in the air and bore sporidia of various forms. (*Vide* Fig. 6, 1).

Their microscopic structure.

In the meshes of the mycelium a sprinkling of the common particles of atmospheric dust were entangled, consisting of fragments of silica, vegetable hairs, particles of carbon, &c. There were also a few small collections of yeast-like cells, and one small mass of bright green protococcoid bodies. Not a trace of bacteria, vibriones or any infusoria could be detected.



1 2

Fig. 6.—Spores and mycelium in rain-water: 1, specimens occurring in Experiment I, magnified 400 diameters: 2, specimens from Experiment III, page 44, magnified 1,000 diameters.

Experiment II.—(*Vide* Fig. 7). Some rain-water was again collected and preserved in the same way, with the same precautions, and from the same locality as in the previous experiment. On this occasion the fall was quiet and steady, and did not consist of a violent thunder shower as then. The only objects visible in the water at first were a few particles of carbon. Forty-eight hours after collection some delicate whitish flocculi had made their appearance in the fluid. Seventy-two hours after the specimen had been hermetically sealed the bell-glass was removed and the flocculi examined microscopically. They were found to consist of dense net-works of mycelial filaments, many of which bore isolated macroconidia in their course. These were brightly refractive and full of protoplasm whilst the joints of the filament on either side of them were almost or totally empty. Many of the filaments were more or less disintegrated, some having their protoplasm broken up into globules, and others being empty and partially decomposed, while their surfaces were coated with granules and short staves embedded in a transparent gelatinous medium. In the fluid around there were also numerous similar bodies, some of which were still somewhat adherent to the gelatinous matter, whilst others were quite free. The staves consisted of two more refractive particles united by a delicate intermediate portion; they strongly resembled bacteria, but showed no vital motion. The felts of mycelium contained a sprinkling of the ordinary constituents of dust entangled among their fibres. After the preparation had been removed from the fluid in the basin, the bell-glass was immediately replaced and pressed down so as to cause the wax again to adhere to the saucer.

Filaments producing macroconidia.

Presence of bacteroid bodies.

Two days afterwards a fresh examination was made. The disintegration of the mycelial filaments had advanced considerably. Some were filled with granular protoplasm; in others this condition was more pronounced, the granules appearing to project on the surface, and in others the filaments were quite empty, but coated with granules like those in the interior of the former ones, together with the staves previously described, embedded in a gelatinous layer.

Numbers of both rods and granules were likewise free in the fluid, but, as before, were quite motionless. There were numerous specimens of the macro-conidial cysts filled with refractive protoplasm, and coming out in strong contrast with the empty, often much disintegrated, filaments in the course of which they occurred. Conidial cells of various forms, isolated or in chains of some length, were also present in abundance. The specimen was enclosed beneath the bell-glass as on the previous occasion and was not again disturbed for five days. The fluid remained perfectly clear and showed nothing beyond the remaining flocculi. A preparation of these was again examined. Disintegration of the filaments had proceeded much further than in the previous specimen, the greater number of the cysts being quite free or with mere fragments of empty tubes remaining adherent to them. Granules and staves were present in great abundance, and in several cases the masses of mycelial filaments were observed to take their origin from common large, brownish, septate, atmospheric spores.

Abundance of Conidia.

Mycelium arising from common atmospheric spores.

The specimen was again sealed and left for six days more. The filaments were then greatly disintegrated but the cysts remained very distinct and were present in abundance. They contained a mass of protoplasm marked with one or two granules and clear spaces, the latter of which could be seen to alter in number and position. In several instances these protoplasmic bodies were observed gradually to work their way out of their cysts, which were then left behind as extremely delicate rings, hardly visible save with careful examination. The process was comparatively slow and the escaping zoospores, for such they seemed to be, *showed a well-developed flagellum in active motion for some time before they were entirely free.* Once detached in the fluid they moved actively about by means of the flagellum as well as by free amœboid extensions of their substance, and in many cases the flagellum temporarily or permanently disappeared, so that, had the process not been actually observed to take place, the two conditions might have been regarded as belonging to distinct organisms. In other parts of the preparation, the mycelial threads had resolved themselves into innumerable conidial cells, while in others they were more or less completely decomposed into gelatinous masses containing granules and bacteroid staves. In one or two places cellular perithecia, somewhat resembling those of *Eurotium*, but of a pyriform shape and with a distinct ostiolum, were present, which, on pressure, discharged a multitude of minute narrow oval spores.

Escape of active zoospores.

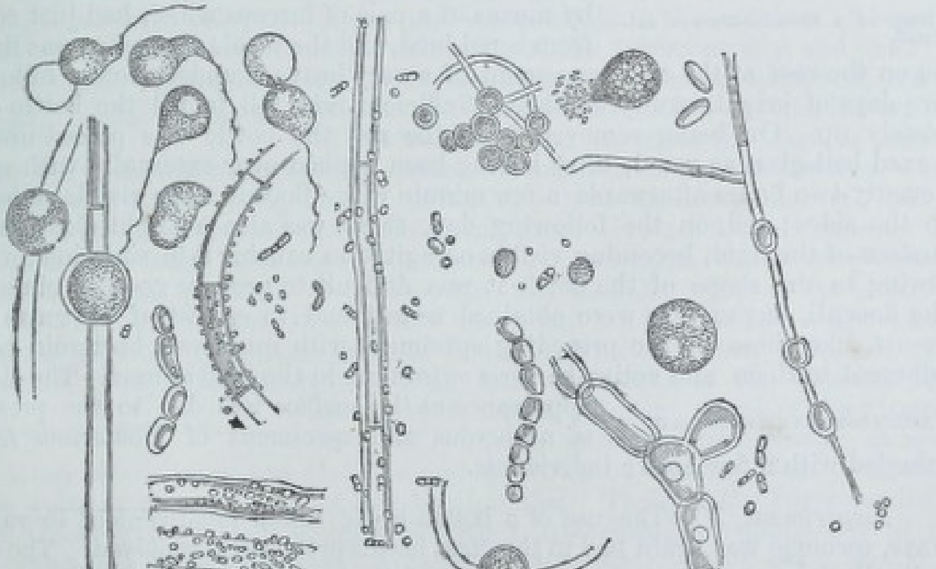


FIG. 7.—Organisms developed in the Rain-water in Experiment II. The Perithecium at the upper part of the figure magnified 120 diameters. The Filament to the right of it magnified 400 diameters. The rest of the objects magnified 1,000 diameters.

After this the specimen was still kept for some days longer, and preparations from it examined at intervals, but no further developments were observed to occur, and no active bacteria ever appeared in it.

Experiment III.—(*Vide* Fig. 6 p. 42). Some rain-water was caught and preserved as usual. On this occasion there had been heavy and continuous rain for nearly twenty-four hours previous to the collection, and the locality was different, the basin being balanced on the top of a railing about three feet high, surrounding a flat roof 22 feet from the ground.

Specimen obtained in a different locality.

Two days afterwards some minute whitish flocculi began to make their appearance in it, but the fluid otherwise remained perfectly clear. On the following day when the bell-glass was removed the flocculi presented a distinct brownish tint to the naked eye, and were, for the greater part, adherent to the sides of the basin. They were composed of mycelial filaments, in some places colourless and in others pale brown. The constituent cells were thick walled and varied greatly in length, for, while towards the extremities of the filaments they were elongated and in the case of the terminal ones often more or less clavate, the majority were very short, often somewhat swollen and in some places passing into chains of distinct circular conidia. (*Vide* Fig. 6, 2). Many free conidial cells, similar to those in the course of the filaments, were also free in the fluid, the younger specimens being almost colourless and the older of a decided olive-green hue and showing various stages of division in their contents. In many of the filaments the protoplasm was broken up into globules, granules, and bacteroid bodies, whilst in the surrounding fluid there was a copious sprinkling of active and still bacteria. Among the flocculi a few particles of sand, amorphous masses, and one or two starch grains were visible.

Characters of mycelium appearing in it.

The last experiment having shown the presence of distinct, active bacteria in the rain-water, several more were tried lest the fact in that case might have been due to water splashed from the surface on which the basin was set, and therefore virtually producing contact inoculation. In order as much as possible to diminish the chance of such an occurrence, a metal rod of over 5 feet in height was chosen as the means of support for the vessel used in collecting the water.

Presence of active bacteria.

Experiment IV.—A small clean glass bottle was filled with spirit and allowed to stand for a short time, the spirit was next emptied out, the bottle firmly fastened to the rod, washed with spirit both externally and internally, and dried by setting fire to the latter and burning it off. A small glass funnel, which had been similarly treated, was then inserted into the neck of the bottle by means of a pair of forceps which had just cooled from a red heat, and the whole apparatus was finally set on the roof at the commencement of a very heavy thunder-shower following two days of bright, sunny weather. Sufficient rain fell to fill the bottle completely up. On being removed from the rod the bottle was placed under a waxed bell-glass as usual, after having been washed over externally with spirit. Seventy-two hours afterwards a few minute white flocculi were visible, adhering to the sides; and, on the following day, there was also a slight cloud on the surface of the fluid, becoming visible on agitation causing it to sink downwards. Owing to the shape of the bottle it was difficult to procure good specimens of the flocculi, but such as were obtained were found to consist of brownish filaments, like those in the preceding specimen, with numerous bacteroid bodies adherent to them and active bacteria swimming in the fluid around. The cloudy appearance at the surface was due to the presence of numerous still specimens of *Bacterium termo*, mingled with a few active individuals.

Rain of a thunder-shower collected.

Active bacteria developed in it.

Experiment V.—The use of a bottle being found inconvenient in various ways, recourse was again had to the glass basins previously employed. The chief difficulty lay in securing them to the top of the metal rod, but this was overcome by means of fixing to the latter three diverging curved portions, united at the top by a ring of wire of sufficient size to include the lower part of the basin and hold it securely in position. This, together with the upper part of the rod, was next passed through the flame of a spirit lamp, and the whole apparatus was then firmly secured in a vertical position at one corner of the roof. A basin was then prepared as usual, and transferred to the rod by means of a heated pair of forceps. This

Apparatus securing absence of splashing.

was done early one morning, after a night of heavy and continuous rain which still persisted. About an ounce of fluid having been secured, the basin was removed by means of a pair of forceps as before and sealed beneath a bell-glass.

Three days afterwards a light bluish white flocculus had begun to appear on the surface, and on the following day it had considerably increased in size. At this time, however, the wax securing the bell-glass became partially detached, and a minute yellowish fly obtained an entrance, fell into the water and was drowned. This accident of course almost entirely destroyed the value of the experiment, but, nevertheless, on the following day, the flocculus, which fortunately was at some distance from the insect, was removed and examined. It was found to consist of mycelium, arising in some cases from large septate spores, and in others from smaller rounded ones. Many of the filaments of the latter were identical with those present in the two previous experiments, and like them bore numerous greenish circular conidia at intervals in their lengths. The protoplasmic contents were generally broken up into globules, and in many places the filaments were disintegrating and thickly coated with gelatinous matter and bacteroid particles. No active bacteria could be detected.

Appearance of a flocculus of mycelium.

Experiment VI.—Immediately on the removal of the basin, in the previous experiment, it was replaced by another, as the rain continued to fall heavily. This was exposed for about two hours, and nearly an ounce of water was collected, containing a few small carbonaceous particles visible to the naked eye. It was covered and sealed as usual, and remained untouched for the same period as the other specimen. No flocculi appeared in it, and, in spite of careful examination, neither mycelium, spores nor bacteria could be detected in it.

Specimen free from mycelium, &c.

Experiments VII and VIII.—On two separate occasions a test tube was exposed, attached to the summit of another metal rod. In one case, about half a drachm, and in the other a few minims of rain, were collected. The tubes were immediately closed hermetically by means of corks which had been immersed in strong spirit for several months, dipped in melted wax before insertion, and thickly covered with more of the same material. They remained untouched for three weeks, and at the end of that period neither spores, mycelium, nor bacteria could be detected in the fluid, which remained perfectly clear and free from the faintest trace of flocculi or cloudiness

Absence of fungi, &c., in specimens preserved for 3 weeks.

Experiment IX.—A basin was exposed as usual on the rod, for two hours during heavy rain which had begun one hour previous to the exposure. There had been several heavy showers on the afternoon of the preceding day, and some rain had also fallen during the night. The specimen was sealed as usual, and, in order to make the contact between the wax and the surfaces of the bell-glass and saucer as thorough as possible, a red hot metal rod was carefully applied all round so as to melt the wax, whilst pressure was applied from above. After five days the cover was removed. A few particles were floating in the fluid, but there were no flocculi visible. The particles were found to consist of the common constituents of air-dust, fragments of cotton fibres, particles of carbon, &c. On carefully scraping the bottom of the vessel with the point of a needle which had been heated to redness a few minutes previously, a little delicate filamentous matter was collected. This consisted of mycelial filaments arising from specimens of the common large atmospheric septate spores. Some of the filaments were full of fresh refractive protoplasm; in others the latter was in detached globules and granules of various sizes, and others were quite empty and more or less disintegrated. Those in the latter conditions were thickly coated with gelatinous matter, containing an abundance of globules and still bacteroid bodies. Numerous active bacteria also swam backwards and forwards in the surrounding fluid. In the course of some of the filaments there were macroconidial cysts, while other bodies of a similar appearance were free in the fluid, accompanied by active zoospores. Both cysts and zoospores were, as a rule, of somewhat smaller size than those in Experiment II, but some of equal size to those in it were also present. In this case, too, the change from the astasic

Specimen containing spores and mycelium.

Presence of active bacteria.

Active zoospores.

to the amœboid condition was observed to take place. One or two atmospheric spores, which had not germinated, were observed, together with three bright green cells of small size, one of which was long-oval, the other two rounded in form.

Experiment X.—A second specimen was collected immediately after the other and sealed in the same way. It also remained untouched for five days. In general appearance, it very closely resembled the former one, showing some suspended particles of carbon, &c., but no flocculi. Here, too, a little filamentous matter, consisting of mycelium, was scraped from the bottom of the basin. Some of this arose from large septate spores; one specimen bore oval sporidia on the summit of clavate lateral branches, and one patch was similar to that occurring in Experiment III, and like it had short joints and greenish conidia; another resembled that in Experiment IX, but was not accompanied by macroconidia or zoospores. In many cases, the filaments contained protoplasm broken up into fragments, or were empty and disintegrating, and here, as usual, gelatinous matter and bacteroid bodies surrounded them. Large numbers of active bacteria were also present. One mass of disintegrating toruloid cells, a large starch corpuscle, and some short fragments of hairs were also observed.

Filaments adherent to the bottom of the vessel.

On reviewing the results of these experiments as a whole, it will be seen that they agree very closely with those obtained by Mr. Samuelson and described in the first section of this report. As in his experiments, spores, mycelium, monads, bacteria and bodies resembling cercomonads and amœbæ made their appearance, not, however, being accompanied by any higher infusorial forms, as was the case in some of his specimens. In seven out of the ten experiments spores and mycelium were observed, and in six of these they were accompanied by monads and bacteria or bacteroid bodies, or both. The spores belonged to forms of common, almost constant, occurrence in specimens of atmospheric dust collected by means of the aeroscope, and their presence may, therefore, be fairly ascribed to their introduction into the rain as it fell, but there is more apparent difficulty in accounting for the presence of bacteria, seeing that such organisms are rarely to be detected in the air. It is no doubt true that they sometimes are present, and it is possible that they may be so constantly and yet not recognisable, due either to alterations in their form dependent on drying, or to their presence in germinal conditions alone; and if the great differences in size and appearance presented by fungal spores, as compared with the fully developed plant resulting from their germination be remembered, it is clear that it is almost useless to expect to be able to recognise and distinguish the presence of bodies of such extreme minuteness as the germs of bacteria must be. But even were they recognisable in atmospheric dust, a difficulty would yet remain in accounting for their multiplication and activity in specimens of fluid like those described above, for various observations are on record by trustworthy authorities, tending to show that bacteria and their germs are deprived of vitality by desiccation. Their presence in the rain-water may, however, be capable of explanation even allowing of their absence from the air, or at all events their absence from it in a living condition.

Results agree with those of Mr. Samuelson.

Difficulty in accounting for presence of bacteria.

The views which prevail at present regarding the nature of bacteria, their mode of origin, and their relation to other organisms, are various, but may, in the main, be referred to three groups or classes. The first and oldest doctrine regards bacteria as independent organisms, multiplying and "breeding true," and never appearing in any medium save as the result of their direct introduction in a developed or germinal condition. DeBary,[1] Hoffmann,[2] Burdon Sanderson[3] and Rindfleisch[4] may be taken as representatives of its adherents. A second school of observers,

Views regarding nature and origin of bacteria.

---

[1] Bericht über die in den Cholera-Ausleerungen Vorgefundenen Pilze. Von Prof. De Bary in Halle.
[2] "Der gegenwärtige Standpunkt der Mycologie, &c." Von Dr. Eduard Eidam, Berlin, 1872, page 190.
[3] App. to "Thirteenth Report of the Medical Officer of the Privy Council."
[4] Eidam. o. cit. page 197. The author here states that Prof. Rindfleisch regards bacteria as incapable of division.

including Professor Huxley[1], Hallier[2], Lüders[3], Karsten[4], Polotebnow[5] and Lister[6] maintains that bacteria are derived from other dissimilar bodies, and specially from fungi. The three first authorities regard them as normal terms in the course of the development of fungi and as capable of reproducing the higher forms from which they are derived; but Karsten, who considers them as "secretion cells" derived from animal and vegetable cells of any kind, and Polotebnow, who believes in their origin from the spores and mycelium of *Penicillium* and other similar fungi, agree in regarding them as incapable of reproducing their parent forms, whilst the latter author even denies their capacity for multiplication or reproduction of any kind whatever. Professor Cohn, in some degree at all events, favours the views of this school, inasmuch as his observations lead him to consider it possible that bacteria may be stages in the development of organisms similar in nature to *Crenothrix*[7]. The third and last doctrine regards them as arising by so-called "spontaneous generation" or abiogenesis and heterogenesis. Bastian[8] and Grimm[9] support this view, the former believing them as well capable of multiplication and reproduction of their kind as of giving origin to higher forms of life, and the latter being now prepared, at all events to allow of their direct multiplication by division, a process the existence of which he formerly denied[10].

Points of agreement in certain doctrines.

The two latter doctrines have so much in common in that they agree in deriving bacteria from other dissimilar bodies, but even here they differ in detail, the one regarding this mode of origin as a normal process of development of certain organisms either in a progressive or retrograde direction, whilst the other looks upon it as an accidental process, and one which, when it does occur, is not a normal term in the development of the parent organisms, but a formation of new, different organisms out of the material furnished by the former ones. Either of them, however, will satisfactorily explain the appearance of bacteria in the present experiments, and, from a practical point of view, the real question of importance does not concern the precise genetic relation of bacteria to the bodies from which they appear to arise, but rather the presence of any bodies in the atmosphere capable of giving origin to them in any way. If they can arise from spores or mycelium, there can be no doubt that the air, in this part of the world at any rate, is a great magazine capable of supplying them to, and accounting for, their appearance in putrescible materials however carefully the latter may be shielded from contact contamination, for spores of various kinds are almost constantly present in it in very considerable numbers. The view that they do so arise appears to derive some confirmation from the present experiments, for in those cases in which no spores or mycelium could be found, bacteria also appeared to be absent, and the appearance and multiplication of the latter in every case occurred coincidently with changes in the protoplasm of the mycelial filaments arising from recognisable atmospheric spores. Of the four specimens free from bacteria and bacteroid bodies, only one contained spores or filaments, the absence of which in the other three was probably due in one case (Experiment VI) to the fact that the specimen was collected after a period of continuous heavy rain, and in the other two (Experiments VII and VIII) to the small surface exposed and the consequent small amount of water collected. That a specimen (Experiment I) should contain spores and mycelium

Conveyance of bacteria by the air the important practical question.

---

1 "Quarterly Journal of Microscopical Science." Vol. X, page 355.
2 "Gahrungserscheinungen, &c.," Leipzig., 1867.
3 "Quarterly Journal of Microscopical Science." Vol. IX, page 32.
4 "Chemismus der Pflanzenzelle." Wien, 1869.
5 "Über den Ursprung und die Vermehrung der Bacterien." Sitzungsberichte der Kaiserlichen Akademie der Wissenschaften. Wien, 1869.
6 "Abstract of a communication to the Royal Society of Edinburgh." Nature, July 10th, 1873, page 212.
7 Beiträge zur Biologie d. Pfl., Breslau, 1870.
8 "The Beginnings of Life" by Professor H. C. Bastian, Macmillan and Co., 1872.
9 "Zur Naturgeschichte der Vibrionen." Von Oscar Grimm in St. Petersburg, Schultze's Archiv, Bd. VIII, page 514.
10 "Nachträgliche Bemerkungen, &c.," Op. cit. Bd. IX, page 118.

and yet no bacteria is no real argument against the origin of the latter from the former in other instances, for the conditions may vary in different cases, in some favouring continuous growth of mycelial filaments, and in others the development of bacteria, either homogenetically or heterogenetically from them. Because in some cases nothing but the common typical fructification of *Aspergillus* appears on certain patches of the mould, it is not denied that the eurotial fructification is capable of arising from a similar mycelial basis under other circumstances. The occurrence of astasic and amœboid zoospores in two of the preparations appears, moreover, to favour the mycelial origin of the bacteria accompanying them, for they, too, are absent as recognisable elements in atmospheric dust, and were actually observed to arise from the mycelial filaments belonging to spores similar to those constantly occurring in it, and although the process of development could not so clearly be followed out in the case of the bacteria, the appearances presented were sufficient, at all events, very strongly to suggest a similar origin for them also. As far as could be ascertained, the course of the phenomena accompanying their appearance was as follows. The original homogeneous protoplasm in the filaments became broken up into separate portions, some of which were rounded and others elongated, while a third form appeared to consist of two refractive globules united by an intermediate more delicate portion. Where the process was more advanced the exterior of the filaments was thickly coated with a gelatinous layer containing numerous bodies, which in appearance very closely resembled those in the interior, and which, together with their basis, seemed to form a species of *Zooglœa*. At a later stage many of the filaments were quite empty, and numbers of the bacteroid bodies were free in the fluid although still motionless, whilst in other cases they were mingled with active specimens of bacteria, swimming rapidly backwards and forwards. All these appearances may be explained on the supposition that bacteria really do arise from dissimilar bodies, but at the same time they may be differently interpreted by those, who, with Dr. Beale,[1] believe in the universal interpenetration of higher organisms with the germs of lower ones, ready to grow and multiply at any moment when favourable conditions are presented to them; still, even if this were the case, the presence of the bacteria would be due to the atmosphere.

Presence of spores, &c., without bacteria, no proof of absence of connection between them.

Phenomena accompanying appearance of bacteria.

May be accounted for by the doctrine of the origin of bacteria from other bodies.

While, however, these preparations showed bacteria, spores and bodies directly derived from the latter, they agreed with those belonging to all the other series of experiments in showing an entire absence of any higher infusorial organisms, and were at complete variance with Ehrenberg's statements regarding the preponderance of animal over vegetable life in the atmosphere. They, moreover, clearly demonstrated the enormous fallacy in all those calculations regarding the absolute number of organisms present in the atmosphere, having as their basis the assumption that all bodies present *after some time* in a fluid which has been exposed to the air, were present as such in the atmosphere. They may be said to have been potentially present, but they were assuredly not necessarily actually so, for, in the present preparations, many filaments were observed to arise from isolated spores, and to give origin to numerous secondary cells, and even, in some cases, to become entirely resolved into chains of conidia—bodies which were present in multitudes in *some* specimens, and in far greater number than the spores from which they arose in almost *all*—but it was evident that the great majority of them belonged to the fluid, and not to the air which had merely supplied their parent cells. A single seed is capable of giving rise to a plant bearing multitudes of new seeds, and it would be just as rational to calculate that the number orginally sown must equal that subsequently produced, as it is to estimate the number of spores present in a given bulk of air from that of those developed in a medium which has been exposed to its influence.

Absence of other Infusoria.

[1] "Disease germs, their Nature and Origin," by Lionel S. Beale, M. B., F. R. S., Churchill, 1872.

The conclusions to be derived from this series of experiments would appear to be as follow:—

Conclusions.

1.—Specimens of rain-water in Calcutta, collected with every precaution to ensure their freedom from contact contamination, sooner or later frequently show the presence of spores, mycelium, zoospores, monads, bacteroid bodies, and distinct bacteria.

2.—They do not, as a rule, contain any of the higher forms of infusoria.

3.—The zoospores are demonstrably derived from the mycelium arising from common atmospheric spores.

4.—There is every probability that the monads and bacteria have a similar origin, but it remains quite uncertain whether their development is due to Heterogenesis, or to the presence of their germs within their parent cells, or as the result of a process of normal development in the latter.

SECTION VIII.

OBSERVATIONS ON THE BODIES PRESENT IN THE AIR OF SEWERS.

A few observations were made in regard to this point, as the air of sewers affords a good basis for the comparison of the characters of common atmospheric air with those of one of known deleterious properties. In procuring specimens of it, it is necessary to secure that they really are typical specimens, and not mere mixtures of sewer air with that of the surrounding locality; and, in order to do so, it is necessary that they should be collected actually within the sewer, and not merely at some opening from which sewer emanations escape. I owe it entirely to the ready assistance afforded to me by Mr. W. Clark, C.E., the Engineer to the Calcutta Municipality, that I was enabled to procure such specimens. On applying to him regarding the possibility of conducting observations on the sewer air, he suggested, as a good locality for the collecting apparatus, a ventilating flue in connection with the silt-pits of the pumping station of the great Calcutta sewers, where the contents are raised to a level allowing of their discharge into the Salt Water Lakes' channel. The accompanying Fig. 8, reduced from a plan furnished by Mr. Clark, will show the nature of this flue and of the locality where the apparatus was placed in procuring the specimens.

Locality from which specimens were obtained.

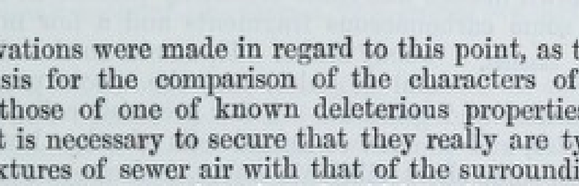


FIG. 8.—Section of the Silt-Pits, &c., of the Calcutta drainage: S. S, Silt-Pits: B, boilers: F, air-flue from Silt-Pits to furnace: C, position of the Aeroscope in the air-flue.

The air passing along the flue ought certainly to afford a good sample of the characters of that in the sewers, coming, as it does, from the pits in which the sewage from all the new drains of Calcutta unites, previous to being raised to the high level by the pumps. Eight experiments were tried with the following results :—

FIG. 9.—Spores and Bacteria from Sewer-air. Magnified 1,000 diameters.

Experiment I.—Fig. 9 a. The aeroscope having been carefully cleaned and prepared as usual was set in the flue on the 18th of June 1873 and allowed to remain there for 24 hours.* A little dust was visible in the preparation when examined by the naked eye.

Specimen containing bacteria, vibriones, oily matter, &c.

The microscope showed a scanty sprinkling of angular silicious particles and amorphous brown masses like those ordinarily present in atmospheric dust. There were also some carbonaceous fragments and a few minute portions of woody tissue. There was an abundance of oily flakes and globules, and the whole preparation was full of fine grey molecules and granules. A few greenish cellules, apparently the spores of *Aspergillus*, and one or two fungal cells of other kinds were also present, together with some short vibrionic staves, and one or two minute bacteria Fig. 9 a. Neither vibriones nor bacteria showed any motion, but this may have been due to their immersion in glycerine.

Experiment II.—The apparatus was set as before on the 21st of June and removed after 24 hours' exposure. The instrument used in this case was a perfectly new one, and on being removed was found to have been much affected by the sewer gases, the brass being blackened, and the iron rod supporting the axis being very much rusted.

Bacteria and spores.

The glass showed a little dust visible to the naked eye. Microscopical examination revealed the presence of numerous carbonaceous, silicious, and amorphous particles, together with a large fragment of woody fibre. There was a great abundance of greyish molecules, a sprinkling of motionless bacteria and vibriones and of spores of *Aspergillus* Fig. 9 b, together with some very delicate yellowish membranous flakes and one or two delicate structureless filaments.

Experiment III.—The apparatus was set at the pumping station on the 24th of June and removed after 24 hours. Hardly a trace of dust was visible to the naked eye. There were scarcely any silicious, carbonaceous or amorphous bodies in it. Oily globules were present in great abundance, the larger ones of a yellowish tint and the smaller colourless. One or two pieces of silk fibre, an insect scale, and a small quantity of greenish-yellow granular matter were also detected. Distinct bacteria occurred in considerable numbers, together with spores of *Aspergillus* and *Penicillium* and a great abundance of fine molecular matter Fig. 10.

Bacteria, spores, and molecular matter.

* In these experiments the short portable stem described in the previous section was employed in order to hold the apparatus.

Experiment IV.—The apparatus was exposed as usual for 24 hours on the 27th and 28th of June. The preparation contained hardly any dust visible to the naked eye. Microscopical examination showed the usual carbonaceous and amorphous particles, with a few angular fragments of silica. Neither oil globules nor bacteria were detected, but there was an abundance of minute greyish molecules.

Specimen free from bacteria.

FIG. 10.—Spores of *Aspergillus* and *Penicillium*. Magnified 1,000 diameters.

Experiment V.—The apparatus was exposed for 24 hours on the 4th and 5th of July. The preparation showed a sprinkling of dust visible to the naked eye and contained one speck of brownish colour which readily flattened out on pressure into a minute flake. A very large quantity of fine molecular matter was evenly distributed throughout every portion of the surface, and a few distinct specimens of *Bacterium termo* were likewise present. Fragments of silica, carbon, and brownish amorphous matter were present as usual in small amount. On examining the flake previously mentioned, it was found to be composed of what appeared to be feculent matter, containing amorphous matter, hairs, and other vegetable *débris*, small zooglœa-like masses, and several ova and minute nematoid worms.

Feculent matter present.

Experiment VI.—The apparatus was again exposed for 48 hours on the 12th, 13th and 14th July. There was no dust visible to the naked eye, but there was a general cloudiness of the preparation shown by the microscope to be due to an extreme profusion of grey molecular matter. Only a very few and minute fragments of silica, carbon, and amorphous matter were present. There was also a tolerably abundant sprinkling of spores of *Aspergillus glaucus* and a few bacteria.

Experiment VII.—The apparatus was again exposed for 48 hours at the pumping station on the 22nd, 23rd, and 24th July. The preparation contained the usual sprinkling of amorphous particles, with a few angular fragments of silica and carbon, and some small granular aggregations of the latter. One cotton fibre, a sprinkling of the spores of *Aspergillus* and one or two fungoid cellules of other kinds were present, but no distinct bacteria were detected. As usual, there was a generally diffused sprinkling of rounded and irregular, greyish molecules and minute particles.

Absence of bacteria.

Experiment VIII.—The apparatus was once more exposed for 48 hours on July 31st and August 1st and 2nd. Molecular matter was present in very great abundance. No distinct bacteria were detected at first, nor did any appear within four days afterwards. A few spores of *Aspergillus* and some very minute fungoid cellules occurred here and there. The preparation also contained a scanty sprinkling of the common silicious, carbonaceous, and amorphous bodies and one or two fragments of fibres of various kinds.

Bacteria absent at first and not developed afterwards.

The principal features characterising the series were the comparatively small quantity of the common coarser constituents of dust in the form of silica &c.; the presence of oily matter in considerable quantity in several of the preparations; the existence of distinct bacteria in four out of the eight specimens; the constancy of the presence of greenish cellules apparently the spores of *Aspergillus;* and the prominent feature imparted by the relative abundance of fine molecular

Principal features characteristic of the series of specimens.

matter. That sand and other bodies generally forming a large proportion of the particles suspended in the outer air should be almost absent in the damp air of sewers is not to be wondered at, and is quite in accordance with the facts observed in the other series of experiments regarding the influence of rain and moist weather. The existence of oily globules in these preparations is interesting, taken in connection with the fact that "fatty matters can be readily recognised" in the gases of decomposition, and that "they require a greater time and more play of air for their complete conversion into inorganic substances" than the other organic atmospheric pollutions derived from the same source.* The existence of distinct bacteria in half of the specimens is also very worthy of consideration, when the extreme rarity of such organisms in a recognisable form, as a constituent of common atmospheric dust, is recollected. Their presence here accords with Cohn's observations on their conveyance by watery vapour,† and suggests that their apparent absence in ordinary atmospheric air is due, not to their not entering it in large quantities, but to the fact that unless the amount of watery vapour present is very great, they lose their characteristic appearance, by which in default of movement they can alone be recognised. The constant occurrence of the spores of *Aspergillus* and the great rarity of other fungal cells is naturally accounted for by the absence of higher vegetation within the sewers, preventing any direct supply of the spores of any of the epiphytic fungi, and by the extremely luxuriant development of *Aspergillus* in Calcutta in almost any situation affording a damp atmosphere and organic matter, conditions amply fulfilled on the sides of the sewers. How much of the molecular matter present in such abundance was really bacterial, and how much mere detritus must remain uncertain, but, whatever its nature, there can be little doubt that it as well as the bacteria was raised and carried by watery vapour.

SECTION IX.

CONCLUSIONS.

General results of all experiments.

The most important of the conclusions to be derived from all the preceding experiments regarding the dust contained in the atmosphere in the vicinity of Calcutta appear to be the following:—

1.—The aeroscope affords a very convenient method for obtaining specimens really representing the nature of the true atmospheric dust.

2.—Specimens of dust washed from exposed surfaces cannot be regarded as fair indices of the constituents of atmospheric dust, since they are liable to contain bodies which may have reached the surface otherwise than by means of the air, as well as others which are the result of local development.

3.—Specimens collected by gravitation also fail to indicate the nature and amount of organic cells contained in the atmosphere, as the heavier amorphous and inorganic constituents of the dust are deposited in relative excess due to the method of collection.

4.—Dew also fails to afford a good means of investigating the subject, as it is impossible to secure that all the bodies really present in a specimen of it should be collected into a sufficiently small space, and, moreover, because it is liable to accidental contaminations, and also affords a medium in which rapid growth and development are likely to take place.

5.—Distinct infusorial animalcules, their germs or ova are almost entirely absent from atmospheric dust and even from many specimens of dust collected from exposed surfaces.

---

* "Air & Rain," p. 477. | † Vide Section I.

6.—The cercomonads and amœbæ appearing in certain specimens of pure rain-water appear to be zoospores developed from the mycelial filaments arising from common atmospheric spores.

7.—Distinct bacteria can hardly ever be detected among the constituents of atmospheric dust, but fine molecules of uncertain nature are almost always present in abundance; they frequently appear in specimens of rain-water collected with all precautions to secure purity, and appear in many cases to arise from the mycelium developed from atmospheric spores.

8.—Distinct bacteria are frequently to be found amongst the particles deposited from the moist air of sewers, though almost entirely absent as constituents of common atmospheric dust.

9.—The addition of dry dust, which has been exposed to tropical heat, to putrescible fluids is followed by a rapid development of fungi and bacteria, although recognisable specimens of the latter are very rarely to be found in it while dry.

10.—Spores and other vegetable cells are constantly present in atmospheric dust, and usually occur in considerable numbers: the majority of them are living and capable of growth and development: the amount of them present in the air appears to be independent of conditions of velocity and direction of wind: and their numbers are not diminished by moisture.

11.—No connection can be traced between the numbers of bacteria, spores, &c. present in the air and the occurrence of diarrhœa, dysentery, cholera, ague or dengue: nor between the presence or abundance of any special form or forms of cells, and the prevalence of any of these diseases.

12.—The amount of inorganic and amorphous particles and other débris suspended in the atmosphere is directly dependent on conditions of moisture and of velocity of wind.

Results compared with those of other observers.

If these results be compared with those obtained by other observers, and detailed in the first section of this report, it will be seen that they agree very closely with those of M. Robin, only differing from them in indicating the presence of a somewhat larger number of spores than appeared in his observations. They differ almost equally from those arrived at by Pouchet and Ehrenberg. It is somewhat difficult to understand how the former observer so constantly failed to detect the presence of spores in his experiments, but there is an apparent reason for Ehrenberg's observation of the predominance of animal forms in the atmosphere. His conclusions appear to have been almost entirely founded on the results of the examination of specimens of dust not directly obtained from the air, but from surfaces on which it had been previously deposited from the air, such as leaves, tufts of moss, &c. Now, as has already been indicated, it is certainly quite unwarrantable to assume that all organisms found in such specimens existed as such in the air, or were even derived from the air in any way. All such surfaces are more or less liable to contact-inoculation; leaves and moss, for example, are liable to this through the agency of insects or birds. Moreover, with regard to many of the organisms detected in such situations, it must be recollected that there is no reason why they should not have arrived there by means of active progression over the surface. When surfaces are wet with rain, there is no reason why Tardigrades, Rotifers, Anguillulæ and many infusoria should not travel over them from one point to another. The journey accomplished at any one time may be small, and its progress soon arrested by defective moisture; but, unless they are deprived of vitality in the interval by desiccation, they are ready for a fresh start when favourable conditions are again presented to them.

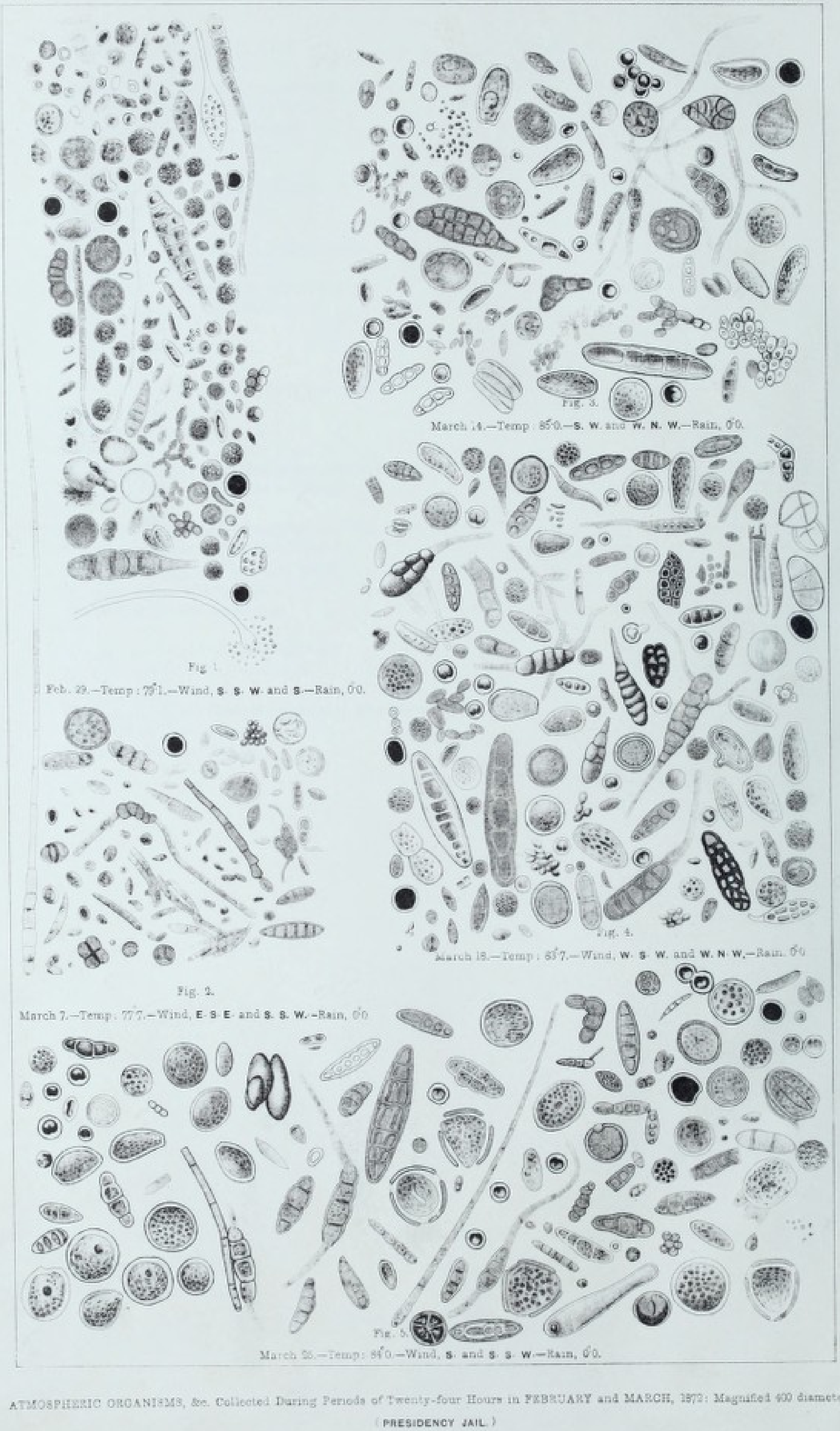
It is hardly safe to venture on the vexed questions regarding the origin of bacteria, but it may, at all events, be stated that the results of the present experiments are certainly not opposed to the belief in the transmission of these organisms in some way or other by means of the atmosphere; for they were actually observed among the particles in moist air, the addition of dry dust to putrescible fluids was followed by their rapid development, and they appeared in specimens of pure rain water.

Although these observations may not appear to encourage the hope of success in discovering the presence of atmospheric particles connected with the origin of disease, it must not be forgotten that they only refer to bodies distinguishable from one another *whilst in the air*, the possibility remaining that many of the finer molecules present in it are really of different natures, and may yet be distinguished from one another by means of their actions or developments. Many interesting questions are suggested in connection with the fact of the presence of such considerable numbers of living cells in the air. What becomes of them when drawn into the respiratory cavities of animals? Is their vitality destroyed, and, if so, how are they got rid of? Are they ever capable of undergoing any development within the organism, and do they then exert any prejudicial influence on the recipient? These and similar questions can only be answered by means of patient and extended experiment, but even such imperfect and superficial observations as the present will I trust serve a useful purpose in clearing away a few of the preliminary obstacles from the path of investigation.

Finer molecular matter of atmospheric dust may include particles of very different properties.

INDEX.

O. S. G. P.—No. 9 S. C. I.—4-12-73—100.



ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in FEBRUARY and MARCH, 1872: Magnified 400 diameters

(PRESIDENCY JAIL.)

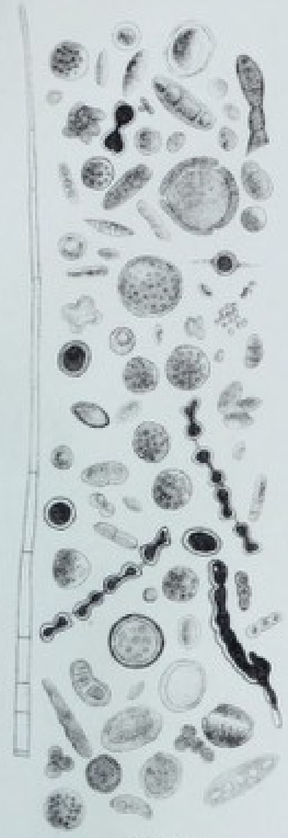


Fig. 1.

Feb. 26.—Temp: 74°·0.—Wind, W. S. W. and S. W.—Rain, 0″·0.

Fig. 2.

Feb. 27.—Temp: 76°·4.—Wind, S. S. W. and S. W.—Rain, 0″·0.

Fig. 3.

March 4.—Temp: 79°·0.—Wind, W. and W. S. W.—Rain, 0″·0.

Fig. 4.

March 11.—Temp: 82°·4.—Wind, S. W.—Rain, 0″·0.

Fig. 5.

March 20.—Temp: 84°·0.—Wind, S. S. W. and S. by W.—Rain, 0″·0.

Fig. 6.

March 28.—Temp: 86°·1.—Wind, S. S. W. and S. by W.—Rain, 0″·0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in FEBRUARY and MARCH, 1872: Magnified 400 diameters.

(ALIPORE.)

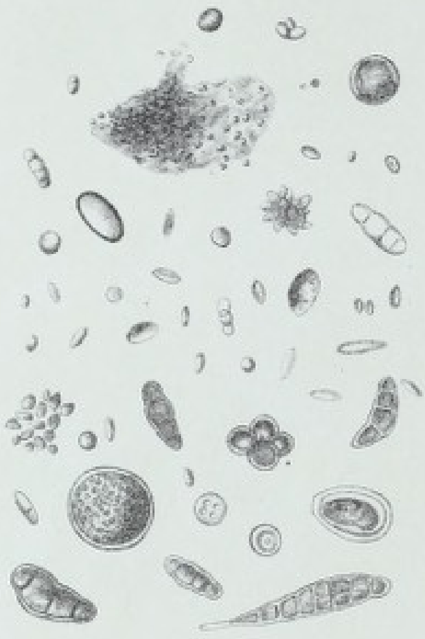


Fig. 1
April 1.—Temp: 78°·8.—Wind, S. by E.—Rain 0"·39

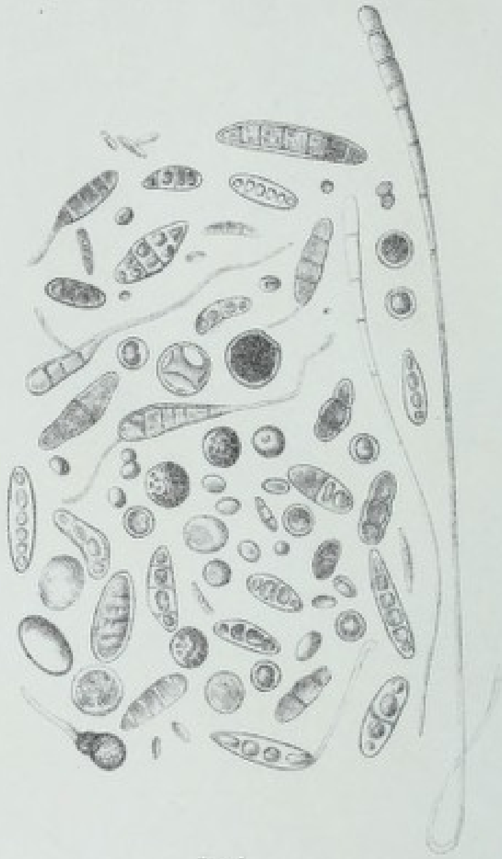


Fig. 2
April 14.—Temp: 87°·8.—Wind, S. and S. by W.—Rain, 0"·0.

Fig. 3
April 22.—Temp: 88°·0.—Wind, S. by W. and S. S. W.—Rain, 0"·0.

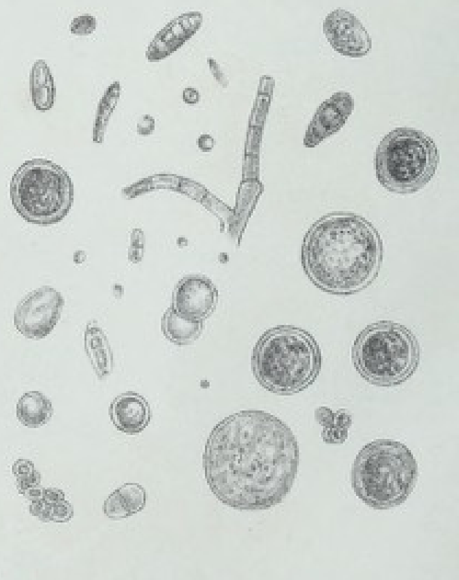


Fig. 4
April 28.—Temp: 88°·7.—Wind, S. and S. by W.—Rain, 0"·0

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in APRIL, 1872: Magnified 400 diameters.

(PRESIDENCY JAIL.)

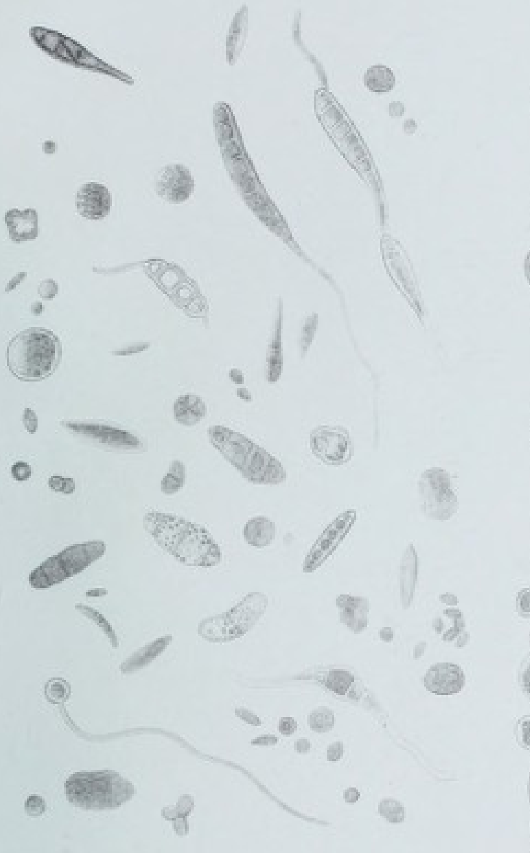


Fig. 1.

April 3.—Temp: 82°.2.—Wind, W. S. W. and S. S. W.—Rain, 0".02.

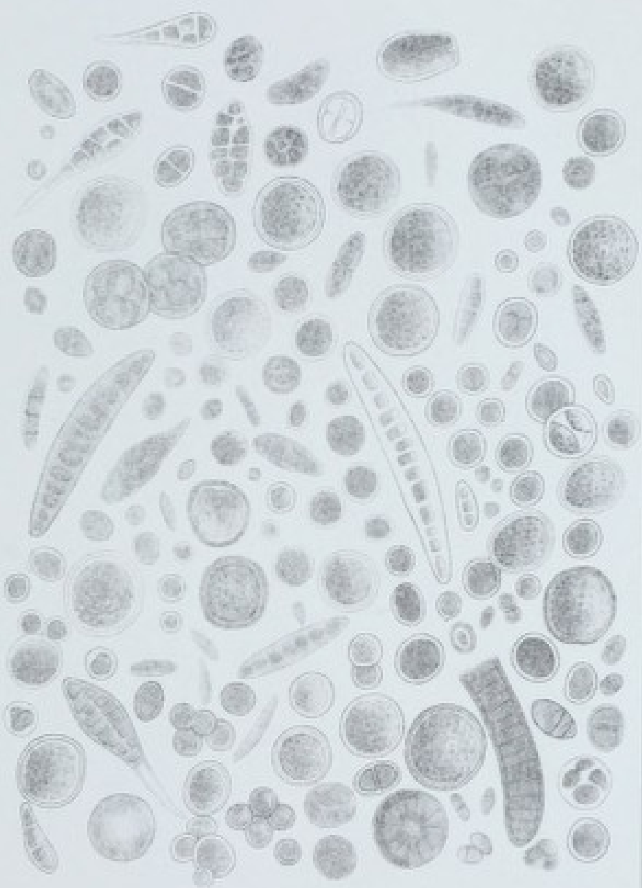


Fig. 2.

April 17.—Temp 86°.3.—Wind, Variable.—Rain, 0".0.

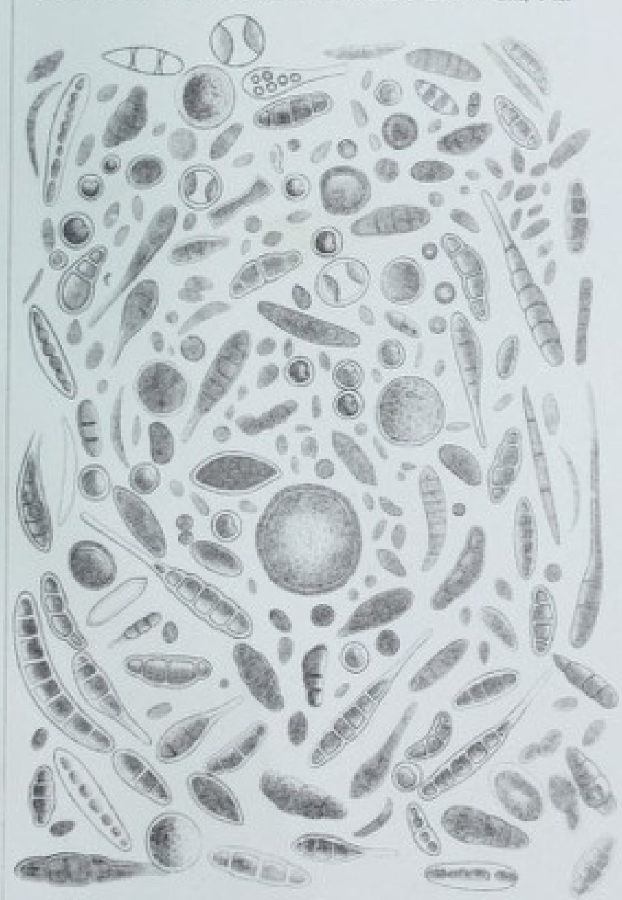


Fig. 3.

April 24.—Temp: 85°.8.—Wind, S. E. and S. S. W.—Rain 0".28.

Fig. 4.

April 30.—Temp: 85°.1.—Wind, S. S. W. and S. by W.—Rain, 0".0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in APRIL, 1872: Magnified 400 diameters.

(ALIPORE.)

Fig. 1.

May 5.—Temp: 88°·0.—Wind, S. by W. and S. S. W.—Rain, 0″·0.

Fig. 2.

May 13.—Temp: 86°·6.—Wind, E. S. E. and S. S. W.—Rain, 0″·0.

Fig. 3.

May 20.—Temp: 84°·5.—Wind, W. S. W. and S. W.—Rain, 0″·12.

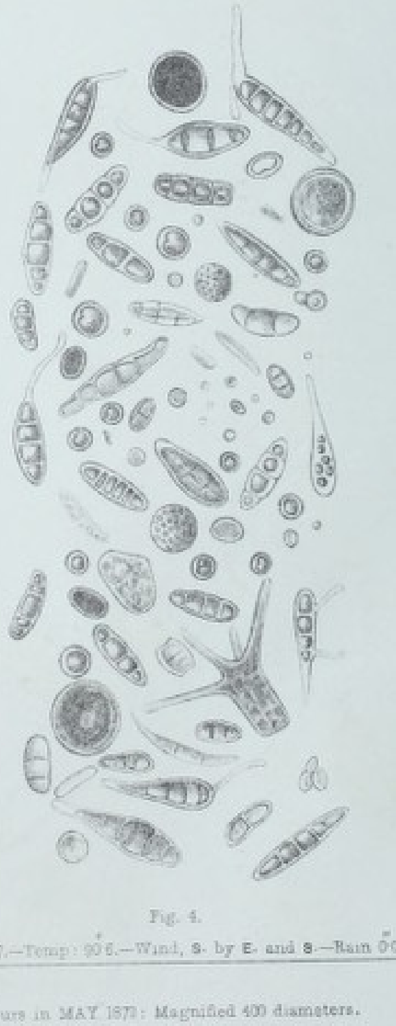


Fig. 4.

May 27.—Temp: 90°·6.—Wind, S. by E. and S.—Rain 0″·0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in MAY 1879: Magnified 400 diameters.

(PRESIDENCY JAIL.)

Fig. 1.

May 8.—Temp: 86°5.—Wind, S. E.—S. by W. and S.—Rain, 0·0.

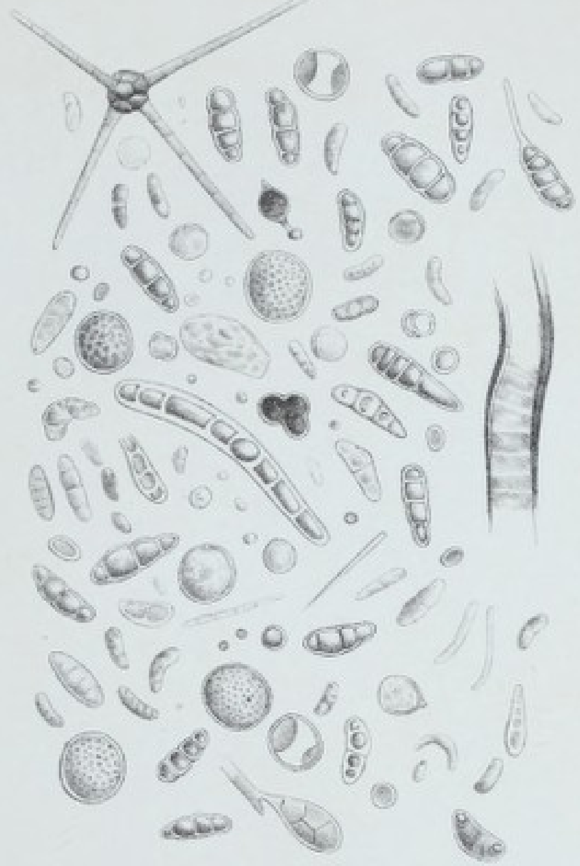


Fig. 2

May 15.—Temp: 88°2.—Wind. S. S. W. and S. by W.—Rain, 0·0

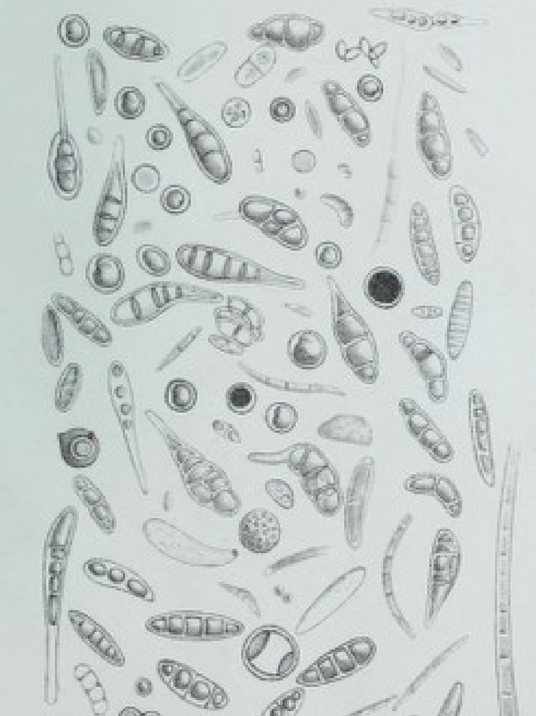


Fig. 3

May 24.—Temp: 87°7.—Wind, S. and S. by W.—Rain, 0·04.

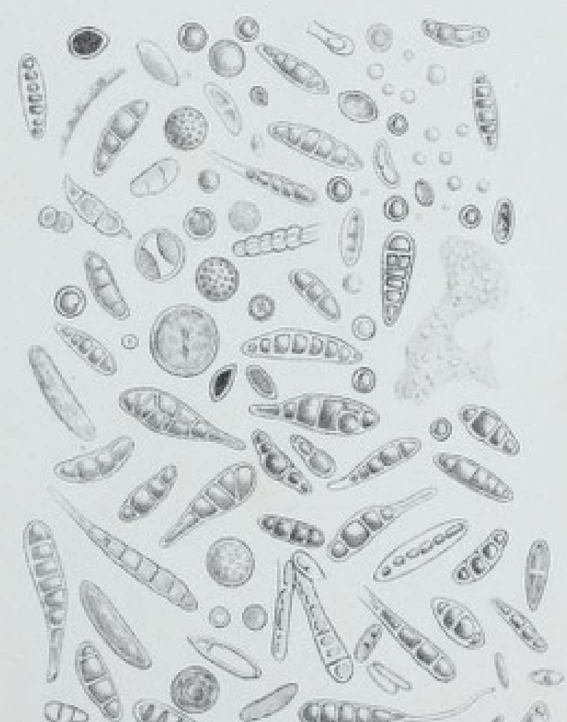


Fig. 4.

May 29.—Temp 89°9.—Wind. S. by W. and S.—Rain, 0·0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in MAY, 1872: Magnified 400 diameters.

(ALIPORE.)

Fig. 1.

June 3.—Temp: 88°·9.—Wind, S. by E. and S.—Rain, 0·0.

Fig. 2.

June 9.—Temp: 85°·0.—Wind, S. by W. and S.—Rain 0·38.

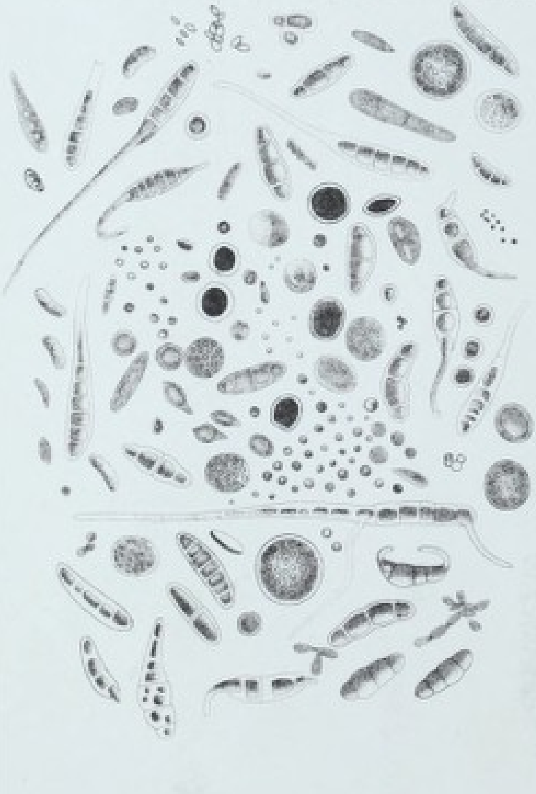


Fig. 3.

June 16.—Temp: 86°·8.—Wind, S. S. E. and S.—Rain, 0·03.

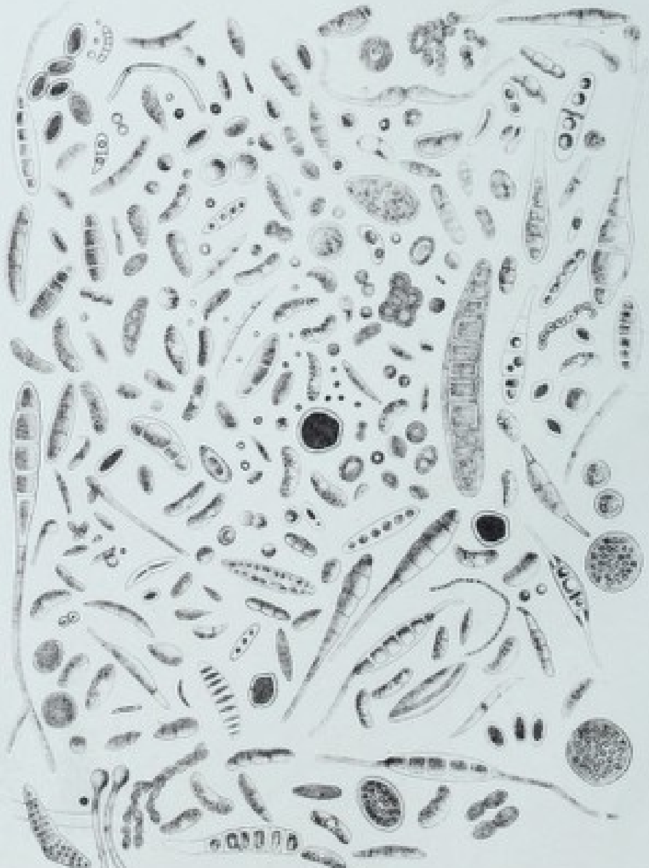


Fig. 4.

June 23.—Temp: 83°·8—Wind, E. by S. E. and S. S. E.—Rain, 0·17.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in JUNE 1872; Magnified 400 diameters.

(PRESIDENCY JAIL.)

Fig. 1.

June 5.—Temp: 87°·4.—Wind, S. and S. by W.—Rain, 0"·33.

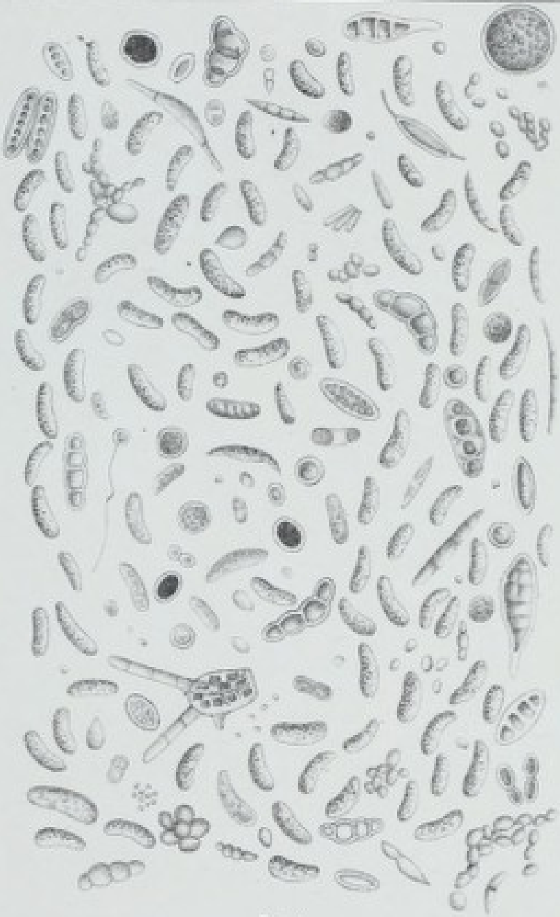


Fig. 2.

June 12.—Temp: 81°·8.—Wind, S. by E. and S. S. E.—Rain, 0"·03.

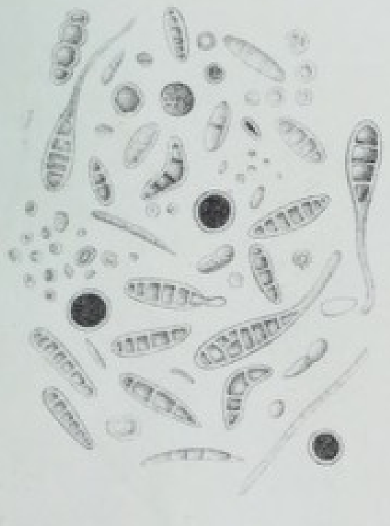


Fig. 3.

June 20.—Temp: 87°·9.—Wind, S. by E. and S. S. E.—Rain, 0"·0.

Fig. 4.

June 26.—Temp; 83°·8.—Wind, E. S. E. and E. by N.—Rain, 0"·45.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in JUNE, 1872: Magnified 400 diameters.

(ALIPORE.)

Fig. 1

June 30.—Temp: 81°·3.—Wind, E. N. E. and E. by N.—Rain, 0″·23.

Fig. 2

July 7.—Temp: 86°·0.—Wind, S by E and S.—Rain, 0″·0.

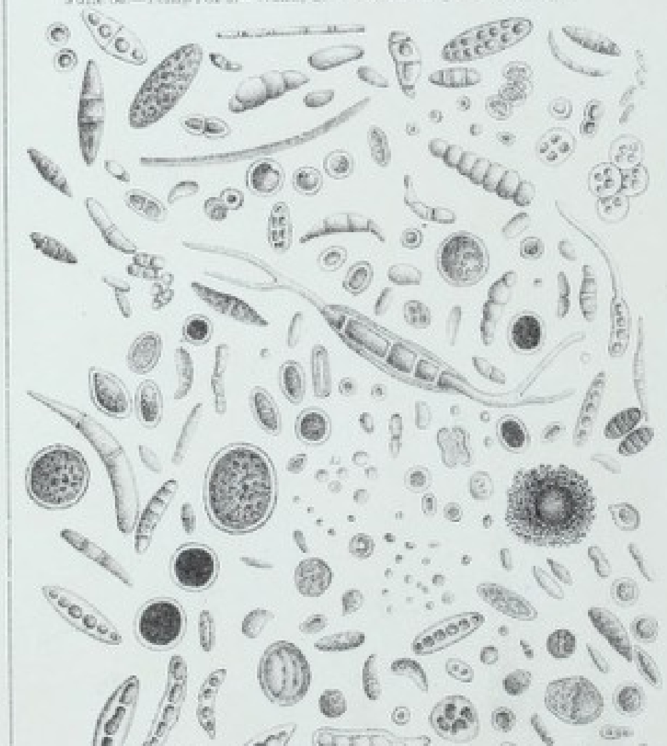


Fig. 3

July 12.—Temp: 80°·9.—Wind, Variable.—Rain, 0″·13.

Fig. 4

July 21.—Temp: 82°·2.—Wind, S. S. E. and S.—Rain 0″·0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in JUNE and JULY, 1872: Magnified 400 diameters.

(PRESIDENCY JAIL.)

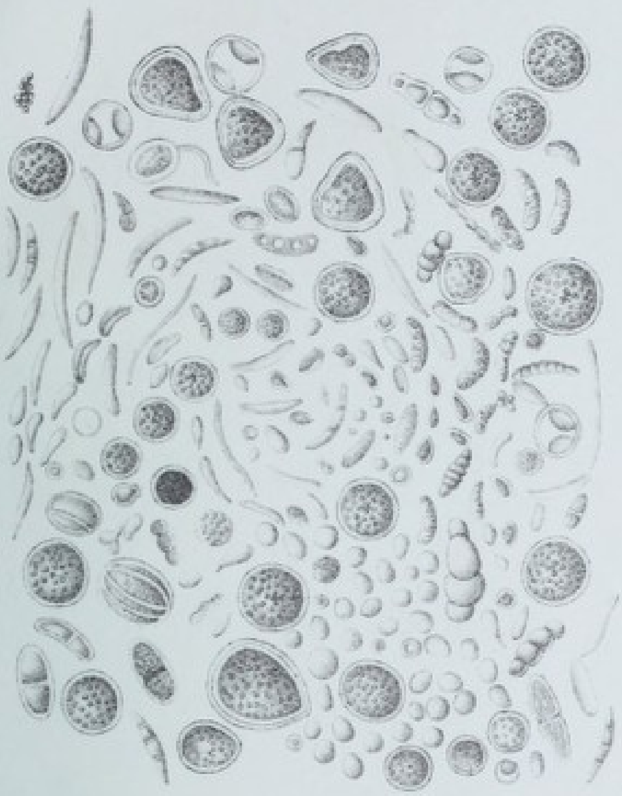


Fig. 1.

July 3.—Temp: 83°1.—Wind, S. S. W.—Rain, 0"07

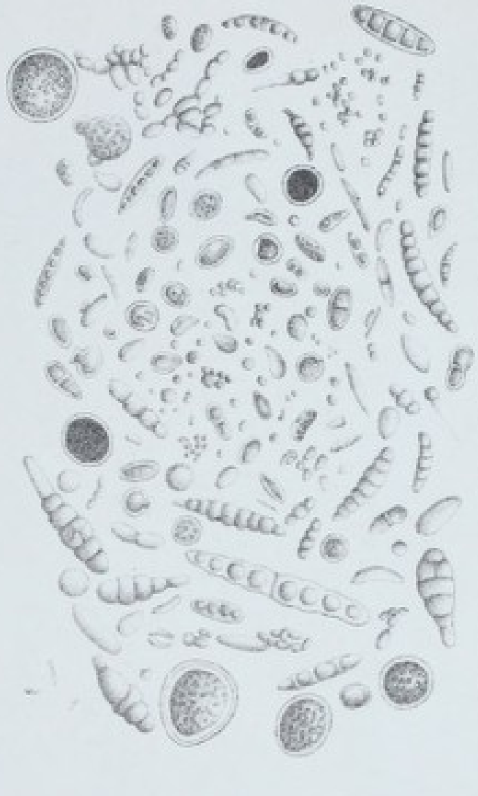


Fig. 2.

July 10.—Temp 83°3.—Wind, Variable.—Rain, 0"11.

Fig. 3.

July 17.—Temp: 84°2.—Wind, S. and S. by W.—Rain 0"13.

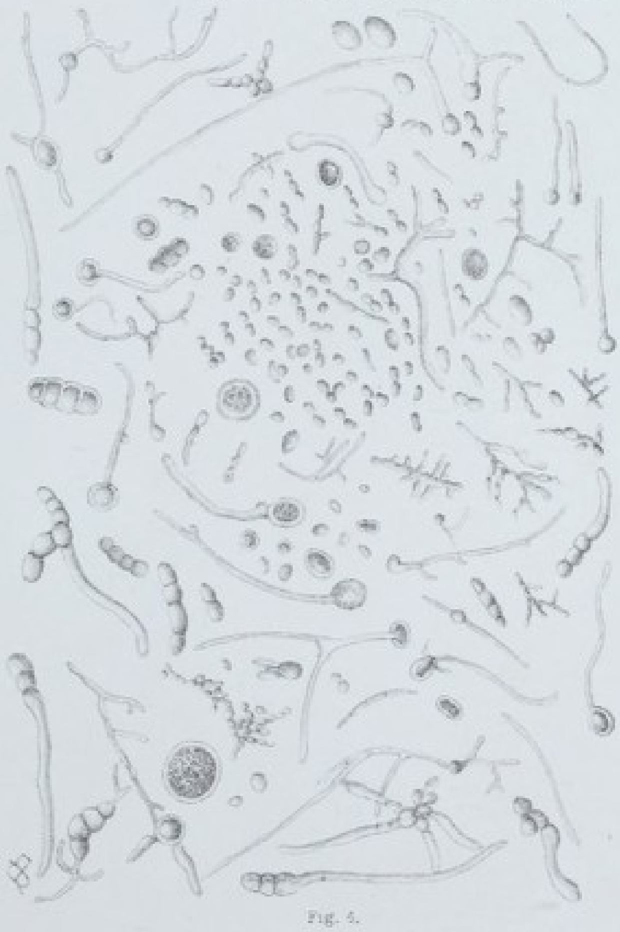


Fig. 4.

July 24.—Temp: 82°4.—Wind, E. and S. S. E.—Rain, 0"25.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in JULY, 1873: Magnified 400 diameters.

(ALIPORE.)

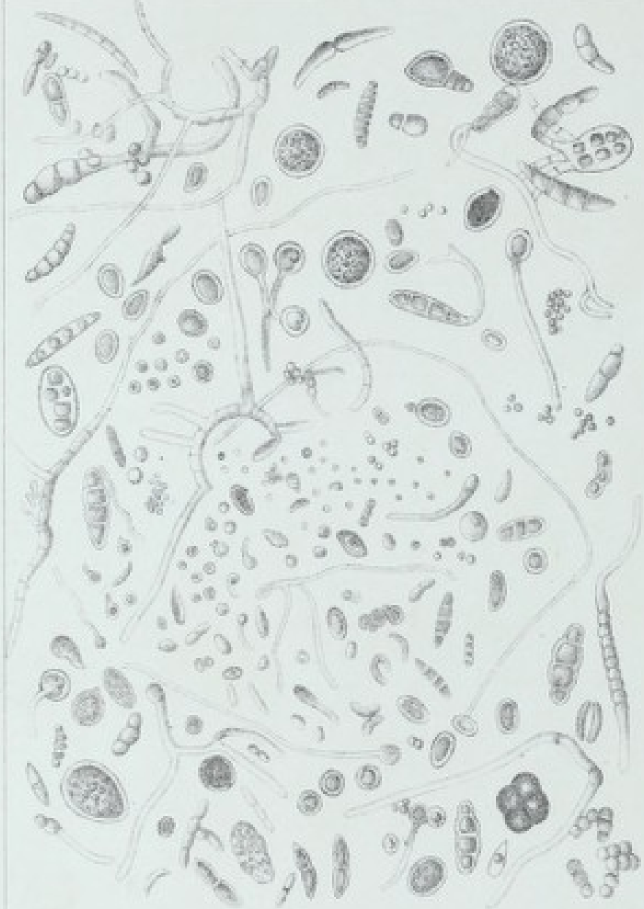


Fig. 1

July 28.—Temp: 82°·4.—Wind, S. S. W.—Rain, 0"·03.

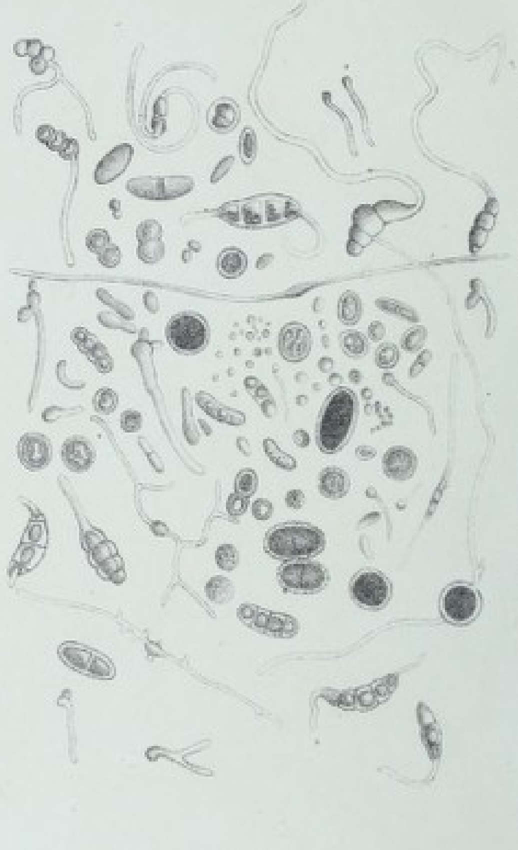


Fig. 2

Aug. 4.—Temp: 84°·3.—Wind, S by E and S.—Rain, 0"·41.

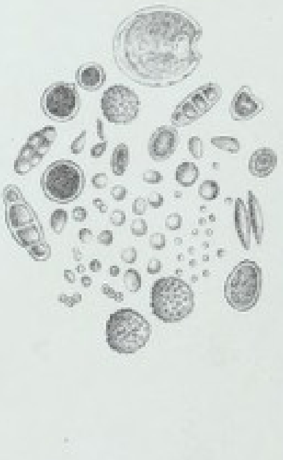


Fig. 3

Aug. 11.—Temp: 83°·6.—Wind, S by W.—Rain, 0"·13.

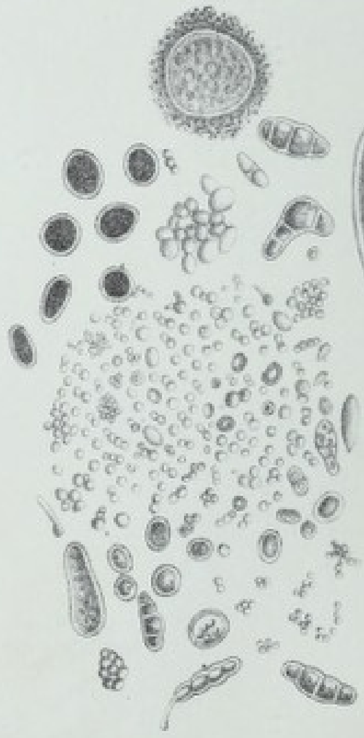


Fig. 4.

Aug. 18.—Temp: 84°·6.—Wind, S. W.—Rain, 0"·0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in JULY and AUGUST, 1872: Magnified 400 diameters.

(PRESIDENCY JAIL.)

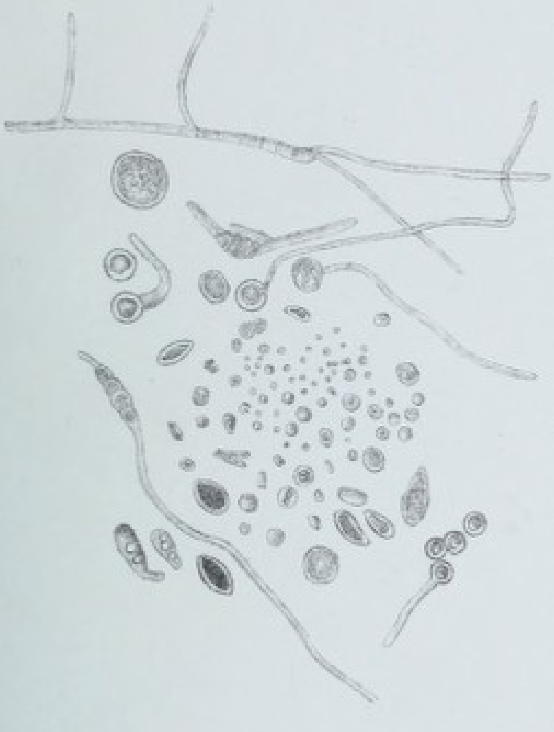


Fig 1.

July 31.—Temp: 83°·9—. Wind, W. and S.—Rain, 0″·02.

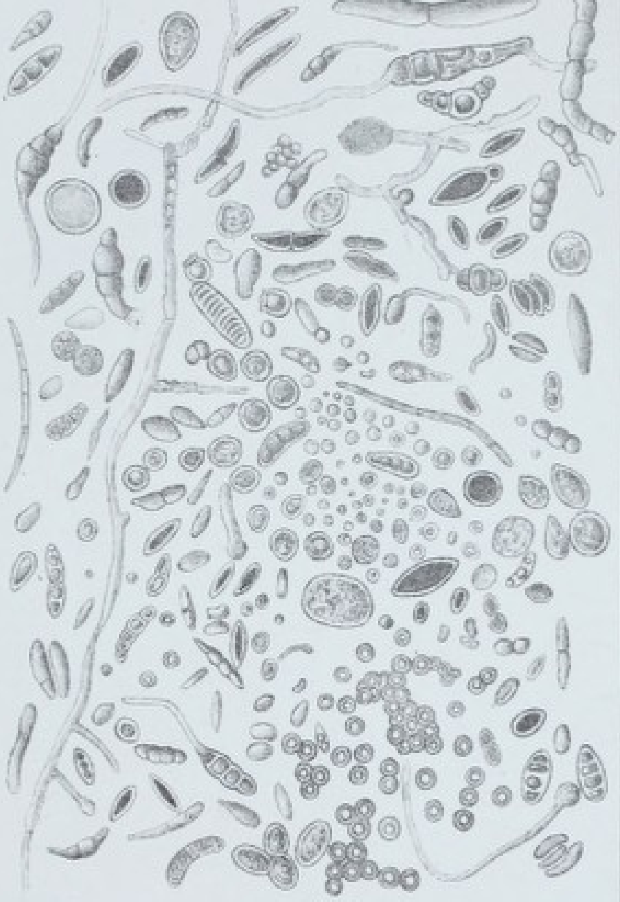


Fig. 2.

Aug. 7.—Temp: 89°·8.—Wind, S. S. E. and S.—Rain, 0″·25.

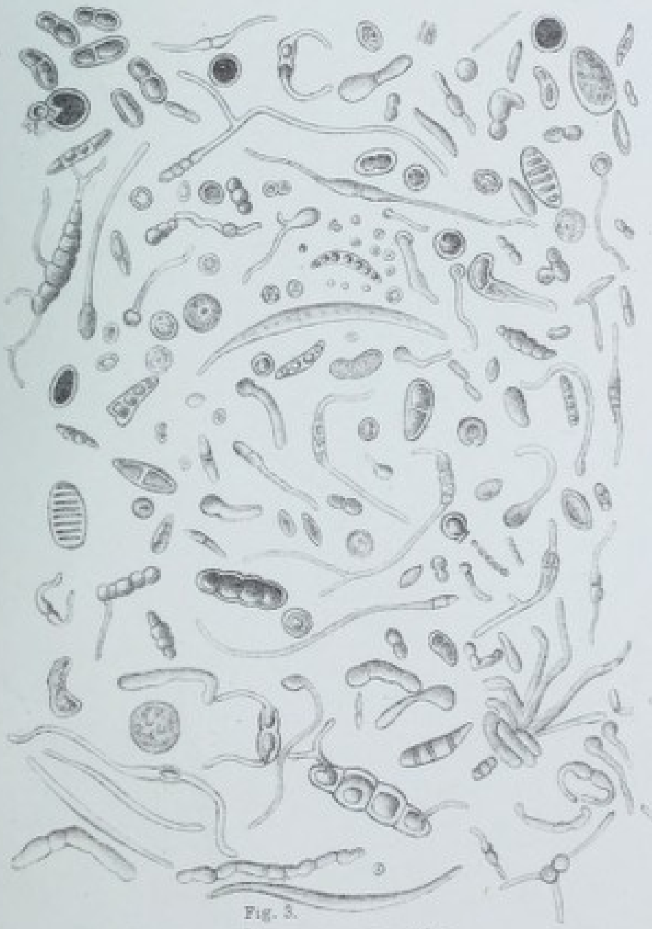


Fig. 3.

Aug. 14.—Temp: 81°·3.—Wind, S.—Rain, 2″·42.

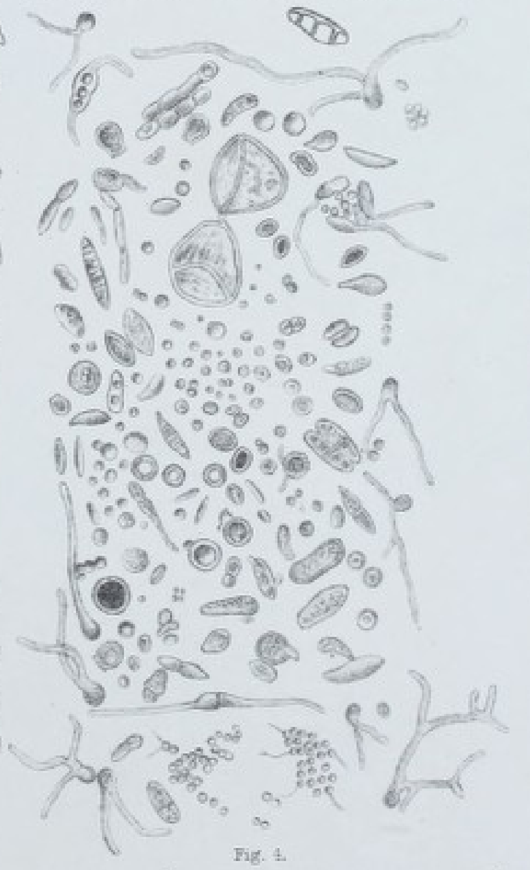


Fig. 4.

Aug. 21.—Temp: 83°·4.—Wind, W. by S. and S. S. W.—Rain. 0″·58.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in JULY and AUGUST, 1872: Magnified 400 diameters.

(ALIPORE.)

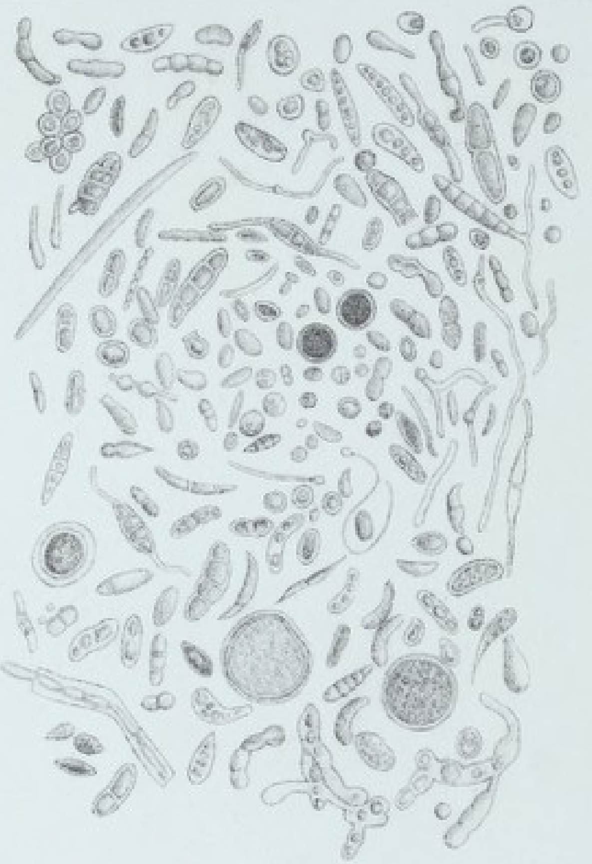


Fig. 1

Aug. 25.—Temp: 81·1.—Wind, S. E.—Rain, 0·10.

Fig. 2

Sept. 1.—Temp: 79·8.—Wind, S. S. W.—Rain 1·05.

Fig. 3.

Sept. 8.—Temp: 85·1.—Wind, W. S. W. and W. by S.—Rain, 0·0

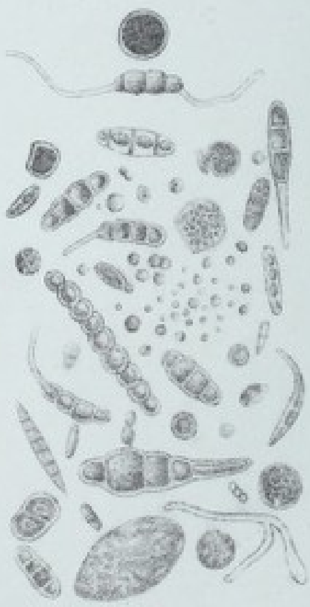


Fig. 4.

Sept. 15.—Temp: 84·9.—Wind, S. S. E and E. S. E.—Rain, 0·20.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in AUG. and SEPT., 1872: Magnified 400 diameters.

(PRESIDENCY JAIL.)

Fig. 1

Aug. 29.—Temp: 84°·6.—Wind, S. and S. E.—Rain, 0"·0.

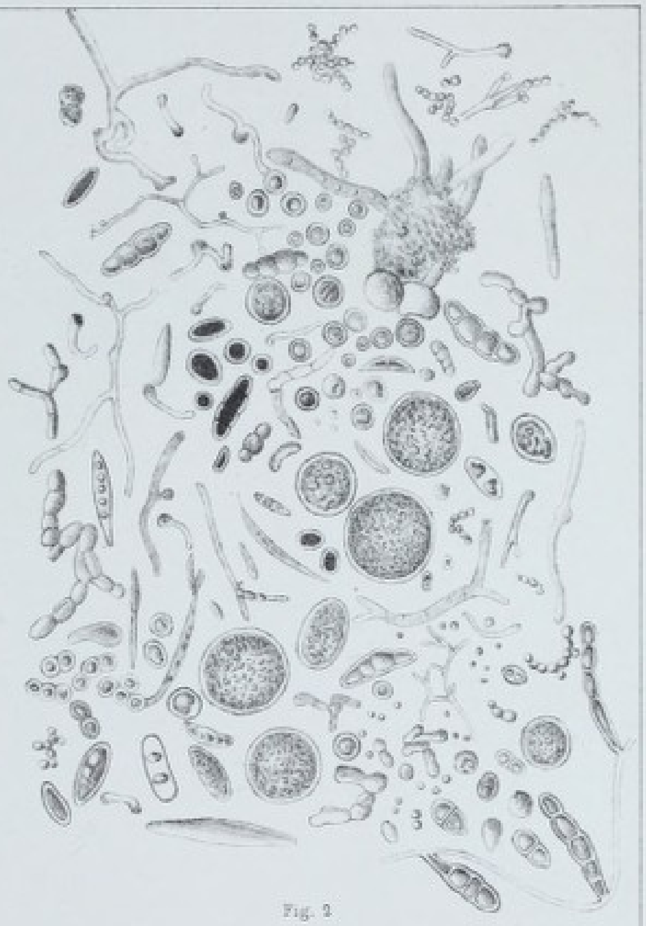


Fig. 2

Sept. 4.—Temp: 82°·4.—Wind, S. W. and S. S. W.—Rain 0"·79.

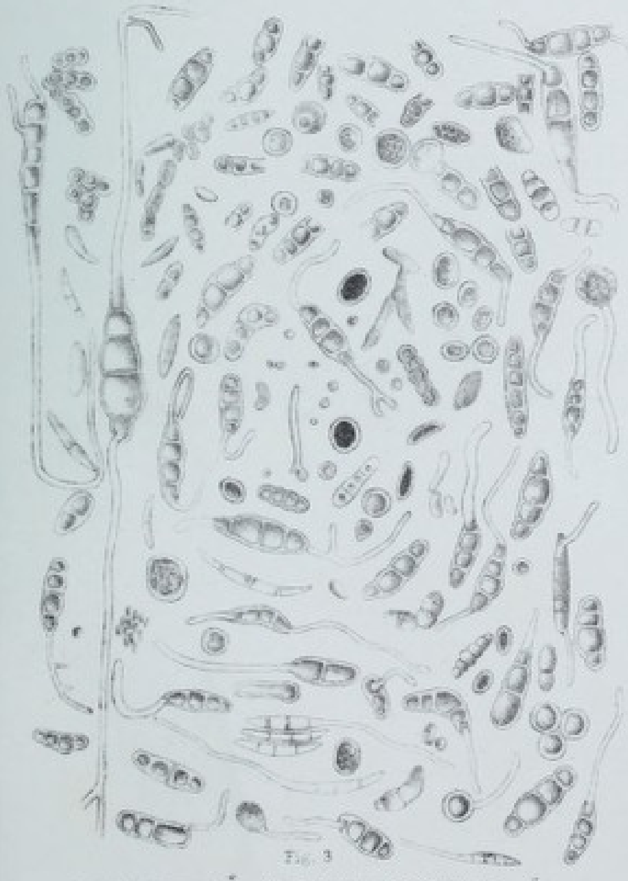


Fig. 3

Sept. 11.—Temp: 87°·3.—Wind, N. W. and N. by W.—Rain 0"·0.

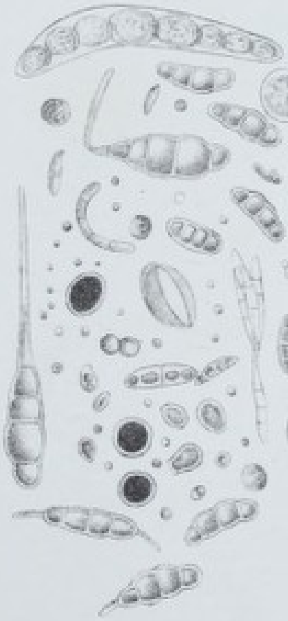


Fig. 4

Sept. 18.—Temp: 80°·4.—Wind, S. E.—Rain, 0"·0.

ATMOSPHERIC ORGANISMS, &c. Collected During Periods of Twenty-four Hours in AUG. and SEPT., 1872: Magnified 400 diameters.

(ALIPORE.)