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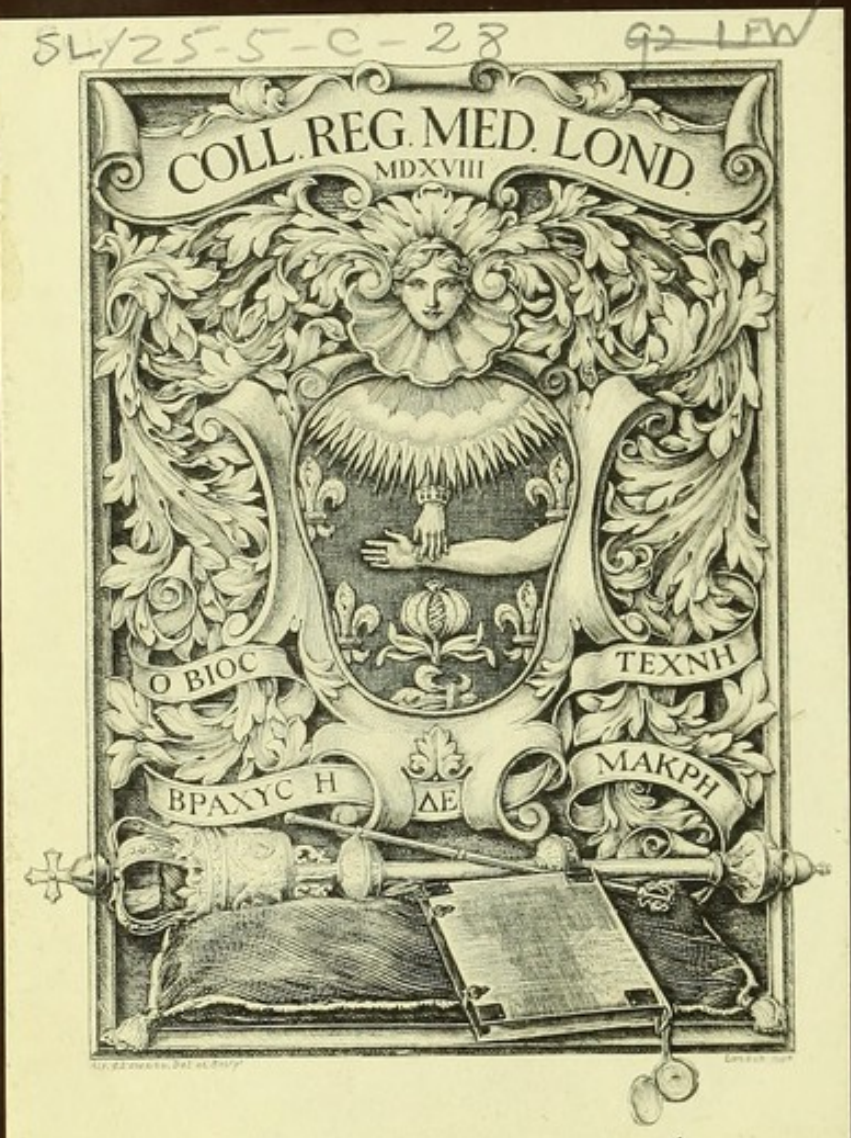

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PHYSIOLOGICAL AND PATHOLOGICAL RESEARCHES.

Presented by the Committee

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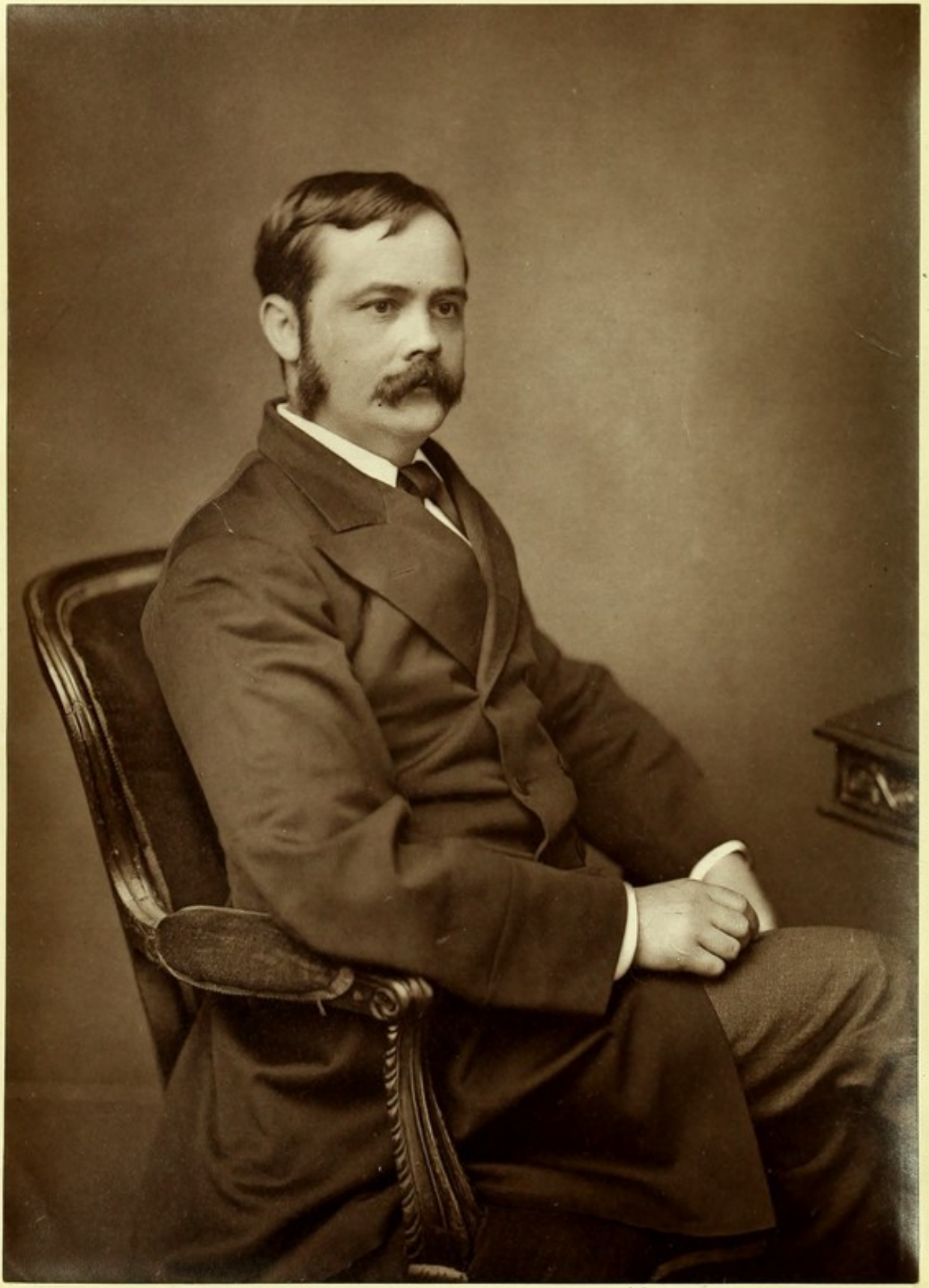

Yours Ever Sincerely

In Memoriam.

PHYSIOLOGICAL AND PATHOLOGICAL RESEARCHES;

BEING A

Reprint of the Principal Scientific Writings

of the late

T. R. LEWIS, M.B.,

FELLOW OF THE ROYAL SOCIETY (Elect). FELLOW OF THE CALCUTTA UNIVERSITY.
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PREFACE.

Soon after the lamented death of Surgeon-Major T. R. Lewis, on the 7th May, 1886, a general feeling arose among his friends and colleagues, that immediate steps should be taken to commemorate the life and work of one who contributed so largely to scientific medicine, and whose death was due to fatal illness contracted while in the active discharge of his duties.

Various proposals having been brought forward and discussed, it was suggested that no more suitable memorial could be devised than the issue of a reprint of Dr. Lewis's scientific reports and papers, with his portrait as a frontispiece, and with a biographical notice. Such reprint would be of the greatest benefit to scientific workers pursuing similar lines of inquiry, as it would place within their reach valuable original researches now scattered throughout the Reports of the Sanitary Commissioner with the Government of India, in Indian journals, and in other publications procurable with difficulty, and absent from many scientific libraries.

This proposal was at once unanimously adopted, a Committee was formed, and soon afterwards circulars were printed and issued to the officers of the Army and Indian Medical Services and private friends, inviting them to subscribe for copies of the work; and to these, as may be seen by the list of subscribers in the Appendix, the response has been liberal and representative.

The Committee acknowledge with pleasure the courtesy of Dr. D. D. Cunningham in giving his sanction to the publication in this volume of the papers which are the joint productions of himself and Dr. Lewis. Dr. Cunningham's name, with that of Dr. Lewis, appears at the head of each of these conjoint papers.

The expense of reprinting has been far greater than was estimated at

the outset, when it was hoped that copies might be supplied to subscribers at a lower price than £1. This is mainly due to the fact, then unknown, that the various costly lithographs, many of them in more than one colour, which were made in Calcutta, had, unfortunately, been rubbed off the stones, and their reproduction has entailed a very great outlay, almost equal to the cost of printing the text.

It has been thought advisable, for the convenience of readers, to arrange the reprinted papers in four parts, according to subject, thus slightly deranging the chronological order, which, however, is maintained under each head, as shown in the table of contents.

THE EDITORS.

31*st March*, 1888.

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BIOGRAPHICAL SKETCH

OF

TIMOTHY RICHARDS LEWIS, M.B.,

SURGEON-MAJOR, ASSISTANT-PROFESSOR OF PATHOLOGY AT THE ARMY MEDICAL SCHOOL, NETLEY.

THE comparatively short life and public services of this distinguished physiologist and pathologist call for more than a passing notice; for the Army Medical Department, its Medical School, and Medical Science sustained an irreparable loss by his death on May 7th, 1886. His loss was so unexpected, that its magnitude could not at once be realised. He was gradually becoming a very centre of scientific influence, and a source of inspiration for earnest work as a teacher, and of genuine research in his position as Assistant-Professor of Pathology at Netley. Of his aims and his methods of work in this official position (which he had held for only three years) we have now but the memory left—a memory which we would not willingly let die, for he exercised in it a most beneficial influence, and accomplished a great amount of work by sheer strength of personal character, having ever before him the ideal of the higher tone of real work. He was, indeed, one of those men "who go on and on working, and full of work and vigour for the Truth's sake;" and he imbued the minds of those he taught with this same keen love of work. Many friends also, young and old, here and in India, looked up to him for advice in the practical affairs of life (other than professional), relying on the soundness and impartiality of his judgment, his sterling candour, and great common sense. The life-history of such a man, and the work he did, is worthy of more than a passing notice for the example it teaches; as, pursuing a lofty ideal, he died at the early age of forty-four, almost before the scientific medical world knew what it possessed in his life.

Timothy Richards Lewis was born at Crinow, Narberth, Pembrokeshire, on October 31st, 1841. He was educated at the Reverend J. Morris's school in the same town, and, at the age of nineteen, proceeded to London to study medicine. He entered the German Hospital at Dalston, where he availed himself of the excellent opportunities afforded of learning the German language, of which he acquired that intimate knowledge which served him so well in his subsequent scientific career. He had, by this time, also acquired a good knowledge of practical chemistry, and became an

expert manipulator. During his stay at the German Hospital he found time to attend some of the classes at University College, London, and there he was so successful in his studies, that he obtained the "Fellowes" silver medal for clinical medicine in 1866. Subsequently he went to Aberdeen, where he proceeded to the M.B. and C.M. degrees of that university, and graduated with honours in 1867.

Eventually, he became a candidate for the Army Medical Department of Her Majesty's Service; and, at the London examination in February 1868, he passed into the Army Medical School at Netley first in the order of merit; and at the end of the four months' course of study, he again passed out at the top of the list. In both examinations (in London and at Netley) he gained exceptionally high marks in all the subjects, and especially in pathology, medicine, and hygiene. His commission, as Assistant-Surgeon in Her Majesty's Army, is dated March 31st, 1868; Surgeon, March 1st, 1873; and Surgeon-Major, March 31st, 1880.

At the time when Lewis entered Netley, the attention of the scientific world was occupied with the so-called fungoid theories, regarding the causation of cholera, propounded by Professors Hallier and De Bary. At the suggestion of the Professors of the Army Medical School, the Secretaries of State for War and for India sanctioned the sending of the two gentlemen who secured the highest marks at the Netley examination, in the British and Indian Medical Services respectively, to Germany, to study for a time under the expounders of these fungoid theories, and thence to India, for the purpose of fully and completely investigating and reporting upon them and the pathology of cholera.

Drs. T. R. Lewis and D. D. Cunningham were the two gentlemen selected for this important inquiry, and instructions were drawn up by the Senate of the Army Medical School for their guidance.

After visiting Professors Hallier and De Bary, they proceeded to Munich, where they were most kindly received by Professor Max von Pettenkofer, with whom Dr. Lewis maintained a life-long friendship and correspondence. Having spent about three months in Germany with these eminent teachers, Drs. Lewis and Cunningham proceeded to India, and reached Calcutta in January 1869, where soon afterwards they were attached for special duty to the Sanitary Commissioner with the Government of India, and from which time until January 1880, Lewis was entirely occupied in cholera and kindred inquiries, usually in conjunction with Cunningham, until, in 1879, the latter was appointed Professor of Physiology in the University of Calcutta.

Having mastered the native language, they were able to pursue their inquiries in remote Indian towns and villages, as well as in the more important cities; and excursions, of longer or shorter duration, were constantly being made wherever cholera was to be found, often in the company of Dr. J. M. Cuningham, then Sanitary Commissioner with the Government of India.

Their first report was published as an appendix to the *Sixth Annual Report of the Sanitary Commissioner with the Government of India*, 1870, "On Microscopic Objects in

Cholera-Discharges;" and, in the same way, most of their subsequent work on this and kindred subjects from time to time appeared, such as "Bladder Worms found in Beef and Pork," by T. R. Lewis; "Cholera in Madras," by D. D. Cunningham; "A First Series of Microscopical and Physiological Observations on Cholera" (1872); a second series (1874); "Soil in Relation to Disease;" and many other reports of a similar character.

During intervals of cessation from cholera investigation, Lewis occupied himself with other important pathological inquiries. In March 1870, when examining a specimen of milky urine in Calcutta, he found that it contained numerous microscopic nematoid worms in a living condition, which he described and figured in a report published in 1870 by the Indian Government, an abstract of which also appeared in the *British Medical Journal* of November 19th, 1870; and specimens were forwarded to the late Dr. Parkes, at Netley. Towards the beginning of July 1872, Dr. Lewis found nine minute nematoid worms in a state of great activity on a slide containing a drop of blood from the finger of a Hindoo suffering from chyluria. These were identical in character with those previously found in the urine, and furnished the first recorded instance of nematoid hæmatozoa having been found in man. Since that time, he continued to make many similar observations, and traced this helminth (the *Filaria sanguinis hominis*) to the blood direct, and to one or other of the various tissues and secretions of the body of numerous patients, all of whom were known to suffer, or to have suffered, from chyluria, or some closely allied pathological condition,—observations which have since been confirmed by other observers in numerous instances. These observations were published in the *Eighth Annual Report of the Sanitary Commissioner with the Government of India*, and also in the *Indian Annals of Medical Science*, vol. xvi., "On a Hæmatozoon in Human Blood; its Connection with Chyluria and other Diseases"; another paper was published in 1874, in the same periodical, "On the Pathological Significance of Nematode Hæmatozoa"; and, lastly, in Quain's *Dictionary of Medicine*, under the article "Chyluria," Dr. Lewis gave a full and masterly account of what is known of this disease in the various countries in which it has been found. Some time after he had written the article for the Dictionary, he succeeded in obtaining what is, beyond question, the mature form of this helminth. On August 7th, 1877, at the hospital of the Calcutta Medical College, two living specimens (a male and a female) were found in the body of a young Bengalee, who was affected with well marked nævoid elephantiasis of the scrotum (elephantiasis lymphangiectodes), associated with the presence of embryo filaria in the blood.

Dr. Lewis began to investigate leprosy in 1873, and in 1877 published, conjointly with D. D. Cunningham, a report on *Leprosy in India*; and in the same year they also published a report on *The Oriental Sore*. In this year he was elected a Fellow of the Calcutta University.

In 1878 he published *Microscopic Organisms found in the Blood of Man and Animals;* and in the same year, conjointly with D. D. Cunningham, a most valuable monograph on *Cholera in Relation to Certain Physical Phenomena*. During this period Lewis was directing much attention to the question of soil in relation to disease; and, in

various parts of the country, Pettenkofer wells (as they are called) were sunk, and data of observations regarding the fluctuations of subsoil-water were recorded. At this time, also, he was summoned to Bombay, to assist in the investigation of the nature of the famine fever there, upon which subject he published two reports. At the end of this year, he obtained fifteen months' leave of absence, six months of which he passed on the Continent of Europe, working in the pathological laboratories of Berlin, Dresden, Prague, Vienna, Munich, and Strasburg, meeting, amongst others, his old friend von Pettenkofer, De Bary, Klebs, Stricker, Recklinghausen, and the great pathologist Professor Virchow, whose demonstrations he constantly attended, and by whom he was most kindly received.

In 1879 he married, and, at once starting for India, reached Calcutta in November of that year.

In 1880 Dr. J. M. Cuningham, the Sanitary Commissioner, having been made Surgeon-General with the Government of India, required the help of Dr. Lewis in the secretarial work, and accordingly the latter accompanied the Government to Simla, from which station, during the ensuing hot season, he made journeys to various places to investigate the pathology of enteric fever; and, although he published no reports on this subject, he has left many manuscript observations, and valuable photographic representations of the intestinal lesions, printed by the Autotype Company.

In 1881 he published a very comprehensive memorandum on "Indian Jail Diets"; and, in 1882, a report on the cholera-outbreak at Aden of the previous year.

In 1883 he was offered and accepted the post of Assistant-Professor of Pathology at Netley, and at once proceeded to England, which he reached in the month of March, receiving on his arrival a letter of thanks from the Secretary of State for India, in which the important work he had done for India was fully recognised.

On reaching Netley, to be associated in his work with his old friend and teacher Professor Aitken, he was distressed to find the latter seriously ill with acute nephritis, and at once took upon himself the whole of Dr. Aitken's duties for that session, preparing such a course of lectures on pathology as is required for the surgeons on probation at Netley, and, in addition, conducting his own work in the microscopical class. In the use of the microscope Lewis was *facile princeps*, and the processes of staining and counter-staining tissue he had literally "at his fingers' ends." He introduced for the first time into this course at Netley practical instruction in the methods of bacteriological inquiry, having previously obtained and arranged the necessary apparatus for all kinds of cultivation experiments with which he had become familiar by his work in India.

At the International Sanitary Conference held at Amsterdam in 1883, and again at the more important Conference at Rome in 1885, Sir Joseph Fayrer and Dr. Lewis were selected by the Indian Government as its representatives; and, by their energetic opposition to the assertion that cholera could be shown to have been imported from India into Europe, they were largely instrumental in securing the adoption of less vexatious quarantine restrictions by the Congress than would otherwise have been the case.

When Koch's theory of a comma-shaped bacillus was put forth as the cause of cholera,

Lewis felt that he must look into the point; and, during the summer vacation at Netley of 1884, he started off to Marseilles and Toulon, to satisfy himself regarding the alleged discovery. On his return, he published a memorandum on the subject, in which he stated that the result of his investigations went to show that the so-called cholera-bacillus was only "an old friend under a new name"—a *spirillum*, broken up by manipulation, which is to be found in the mouths of healthy persons.

During the last year of his life, he was appointed honorary secretary to a Committee convened by the Secretary of State for India, under the presidency of Sir William Jenner, to consider a report by Drs. Klein and Gibbes, who had been sent to India by the Government to investigate Koch's alleged discovery, and other points connected with the history of cholera. He succeeded in drawing up a report, which was signed by every member of the Committee.

Only a fortnight before the commencement of his serious and fatal illness the value of his many years of patient and laborious work was recognised by the Council of the Royal Society, who recommended him for election as one of the Fellows for the present year; and, had he lived but a few more weeks, Lewis would have actually received this, the "blue ribbon" of science.

His sound common sense, his habit of going to the very root of every question, his accurate and clear judgment, eminently fitted him for the investigation and exposition, so far as he could find the light, of the intricate and mysterious diseases it was his lot in life to study. He devoted himself to his work with untiring and resistless energy, never resting, never satisfied, and, like a true student in the fields of science, always making one revelation the point from which to search for greater light, from which to start upon more extended inquiries.

Now he is at rest. "We may not stir the heaven of his repose with loud-voiced grief or passionate request or selfish plaint;" but in the sudden loss of a useful life at so early an age, recognise at once "the burden and the mystery of all this unintelligible world."

PART I.

CHOLERA.

A REPORT

ON THE

MICROSCOPIC OBJECTS FOUND IN CHOLERA EVACUATIONS, ETC.

BY

T. R. LEWIS, M.B.

[*Of Date* APRIL, 1870.]

In accordance with instructions issued at the commencement of this inquiry, attention has been specially directed towards obtaining facts bearing on the truth or otherwise of two hypotheses regarding the cause of cholera—namely, the theory of its fungoid origin, particularly the one advanced by Professor Hallier of Jena; and the theory of the connection existing between cholera and certain conditions of the soil, promulgated by Professor Max von Pettenkofer of Munich.

In both theories the existence of a specific poison of an organised nature is maintained—a *germ;* and both savants believe it to exist in the alvine discharges of a person affected with cholera. The Munich Professor does not risk an opinion as to whether it belongs to the animal or to the vegetable kingdom, but infers that the soil is the *nidus* in which it grows; whereas Professor Hallier maintains that it multiplies in the human body, and unhesitatingly affirms it to be a fungus.

An account of the observations which have been made in order to test the views advanced by Professor Hallier will occupy the first portion of the report; and, as in the course of the investigation my attention has been directed to a consideration of the microscopic objects which are found in the evacuations of cholera patients, a description of them will at the same time be given; together with illustrations of various initiatory experiments bearing on the general question of "disease-germs." [The second portion of the report mainly deals with Professor Pettenkofer's theory.]

I. CONCERNING THE THEORY OF THE FUNGOID ORIGIN OF CHOLERA AND THE MICROSCOPIC OBJECTS FOUND IN CHOLERAIC EVACUATIONS.

THE theory of the fungoid origin of cholera is based upon the result of certain experiments instituted by Professor Hallier,* with the view of ascertaining whether any special organisms could, by means of artificial cultivations, be obtained from choleraic discharges. These experiments have been repeated many times in Calcutta, but as the daily notes of each cultivation would occupy so much space, I propose giving a short summary of a few of the cultivations, illustrated by some of the *camera lucida* drawings which have been accumulated during the investigation. It may, however, previous to doing so, be well to state, in as few words as possible, what the theory really is. As the Professor has published the result of his labours, a short epitome of his *brochure*, weeded of as many technicalities as such a subject will permit, together with a selection of the leading figures in the plate attached to the book, will, it is thought, best serve to convey his meaning.

Some choleraic discharges were sent to the Professor at Jena, obtained from a patient at Berlin during the epidemic of 1866, and another specimen from a patient at Elberfeld during the epidemic in 1867. These were examined microscopically, and found to contain:—

1. *Cysts* of a yellow or brownish colour, which he for some time believed to be the fructification of *urocystis;* some of these had a very irregular outline, and at first sight seemed to possess no organic structure, caution being necessary not to confound them with masses of fat; application of pressure was, however, found sufficient to discriminate between them. A drawing is given of some of these in a swelled, broken up condition (Plate I, 1).

2. Here and there a few other cysts were seen more distinctly organised, considered to be of the same kind as the foregoing; they were spherical or oval cysts varying considerably in size, enclosing a number of yellowish shining spores; the spores also varying in size, as may be seen by a reference to the accompanying figures (Plate I, 2).

3. Groups of swollen gelatinous *spores* surrounded by finely molecular matter (Plate I, 3). Others appear granular, and some show indication of fission.

4. *Micrococcus.*—The molecular matter just alluded to, supposed to have originated from the breaking up of the plasma in the "spore," a little heap often being observed, corresponding to the previously existing spore, called a "micrococcus colony" (Plate I, 4 *a*), which at *b* is still further broken up; at *c* a group of "colonies" is seen corresponding to the mass of spores previously contained in a cyst whose walls have disappeared. The minute protoplasmic molecules constituting these colonies were seen to adhere to various objects in the fluid, and especially to the particles of epithelium—in fact, feeding upon them; this being invariably the way in which vegetable parasites first attack animal

* "Das Choléra Contagium." Von Dr. Ernst Hallier, Leipsig, 1867.

tissues. In the midst of these molecules larger ones were observed (Plate I, 5), which have been figured in a still more advanced stage as torula-like formations at 6. This condition being, according to Professor Hallier, the transition stage to the development of the higher forms of fungi.

A series of cultivations was carried out in order to prove that these bodies were organically related to each other; namely, that the irregularly defined cysts were advanced stages of the cyst with sharp contour and well-marked spore contents; that the circular gelatinous-looking bodies were originally contained in capsules; that the capsules had been borne on a filament; that the filament had originated in a "micrococcus" cell; and that the "micrococcus" had been derived from the disintegration of these gelatinous spores. Portions of the discharges in question were isolated, and placed upon various substrata—beef, starch-paste, slices of lemon, etc.—so as to supply the "micrococcus" with other nourishment than the epithelium of the intestinal canal, the disorganisation of which substance is, according to Professor Hallier, the prime cause of cholera.

The results of these cultivations may be thus briefly described. During the first two or three days the micrococcus rapidly increased in amount, and developed into nucleated cells, which arranged themselves into chains, as already observed to exist to a slighter extent in the original evacuation. In some cases a thin pellicle formed (*mycoderma*), which, on being lifted, frequently broke down into round balls like the "micrococcus colonies;" the torula-cells about the fourth day were seen to germinate, the ends of the filaments having a linked appearance (6), which, continuing to grow, presented the appearance usually seen in *oidium lactis*. In the course of a week the filaments assumed a branched and sacculated appearance (Plate I, 7, 9), these saccules or joints (termed "macroconidia") being capable of germinating like the spores. The spores were on several occasions seen to produce a peculiar form of fructification, considered by Dr. Hallier to be degenerated *Tilletia caries* (smut), (Plate I, 9), and on one occasion a spore somewhat like that of smut was detected (*sp*); a few abortive attempts at the formation of spore-containing-cysts were also seen. In a few instances, however (about the 9th day), the filaments were observed to bear unmistakable cysts, some with the contained spores very evident (Plate I, 8), and others in which this condition was less clear.

The nearest approach to the development of the cysts, corresponding to those in the discharges, which reminded the Professor so strongly of Urocystis, is figured (Plate I, 10), and the germination of the same at Plate I, 11.

The inferences drawn by Dr. Hallier from these experiments in a few words are, that cholera is produced by a species of fungus belonging to the *ustilagines* or smut group. This fungus is a polycystis, similar to that attacking the rye only in Europe, but which the Professor believes attacks the rice plant in India; grounding this belief on the fact that, in the tissue of growing-rice plants watered with choleraic discharges, bodies were detected which he considered identical with the cysts found in the evacuations, thus accounting for the belief frequently expressed by the older

writers, that cholera was generated by the consumption of rice in a diseased condition. The author has since modified his views as to the species of fungus in question, but retains the opinion that, whatever the fungus may be called, it closely corresponds with the fungus observed to develop in soil contaminated with choleraic discharges. It will now be seen that Professor Hallier believes that he has established an organic connection between the two kinds of "cysts," "spores," and "micrococcus."

The questions naturally arise—(1) Are there such bodies in the choleraic discharge examined in India? (2) What are they? and (3) Are they found under similar circumstances elsewhere?

SECTION I.—"CYSTS."

Dr. Hallier appears to have derived the first idea of cholera cysts from the engravings of the "cholera bodies" of Drs. Swayne, Brittan, and Budd, in the year 1849, as reproduced in M. Robin's work on *Vegetable Parasites.** For, after stating that they are undoubtedly of the same nature, judging from the drawings, of those seen by him, a severe reproof is administered to the French author for the summary way in which he disposed of the "cysts" of the Bristol doctors. As these "cysts" have been the subject of discussion for more than twenty years, without any definite conclusion as to their real nature having been attained, a few observations concerning them may not be uninteresting in illustration of their natural history. In September 1849, Dr. Brittan published a description of the bodies observed by him, termed "annular bodies," in the *London Medical Gazette;* this term comprising bodies varying considerably in size and appearance—large masses corresponding to Hallier's cyst, and smaller bodies which probably correspond to Hallier's spores. Mr. Brittan did not attempt any cultivation so as to connect the one class with the other, but inferred that they were the same in different stages of development, because he had observed something like a connection between the size with the severity and duration of the disease. The late Professor Quekett, of the Royal College of Surgeons, coincided with him in the belief that they were different stages of the same body, and of a fungoid nature. Mr. Swayne also announced that he had discovered certain cyst-like bodies which were named "cholera-cells," drawings and descriptions of which he published in the *Lancet* about the same time as Mr. Brittan. He also believed that the larger and smaller bodies figured were mere stages in the development of the same thing. Dr. Budd believed that he found similar bodies in the water of tainted districts, and designated them "cholera fungi." These announcements caused considerable excitement at the time, which was somewhat lessened when Mr. Busk announced that the bodies in the sample received by him were a species of uredo (*Uredo segetum*), the bunt of wheat, illustrating his statement by the removal of bodies like the one in question from a loaf of ordinary brown bread. The College of Physicians appointed a Committee of Inquiry, and Drs. Baly and Gull drew up a

* "Histoire Naturelle des Végétaux Parasites." Atlas, Pl. XII., Figs. 4, 5.

report, in which the small bodies are said to be either carbonate of lime (probably from the aromatic confection mixture taken), disintegrated blood-cells, or starch particles; the larger ones figured by Dr. Budd to be probably accumulations of starch cells with disintegrated particles of vegetable tissue, and those of Drs. Brittan and Swayne to be some species of bunt, as identified by Mr. Busk. The Reverend M. J. Berkeley (the greatest authority on fungi we have), on being referred to, declared that the specimens he received were not fungi at all, so that evidently the propounders experienced some difficulty in recognising their own "bodies," otherwise such microscopical experts as Mr. Berkeley and Mr. Busk would not have been supplied with such entirely different substances.

Here the matter rested until Professor Hallier observed a resemblance between the cysts in the choleraic discharges examined by him, and those figures in M. Robin's book, which figures are here reproduced (Plate II, Fig. ii), as being the only criterion we possess of what Hallier really means when he speaks of cysts; the only drawing published by him of the mature cyst being that of a ruptured one (Plate I, 1).

In the examination of cholera dejecta which I have made in Calcutta and in the North-Western Provinces, many cyst-like bodies were observed in the choleraic dejecta observed in India, and these in many cases closely resembled the ones figured in M. Robin's work, but were not of such universal occurrence as the attention they have obtained would have led one to expect; indeed, frequently absent altogether.

The "cysts" figured by Drs. Brittan and Swayne (the greater part of which are here reproduced from the drawings accompanying the original articles of these gentlemen) are certainly the kinds most frequently present in evacuations, as the fact that the following observations concerning them were completed before either the original figures or copies of them had been seen would tend to show.

They may be divided into two classes. The principal figures in Dr. Brittan's drawing will serve as an illustration of one kind (Plate II, Fig. iii, 1), and the leading figures in Dr. Swayne's of the other (Fig. iv, 1-4). As the two classes are copied in M. Robin's work, and Dr. Hallier does not intimate his belief that they are not of the same nature, it will perhaps be best to allude to the two, so as to leave no stone unturned in the matter. That they vary much in their nature will be manifest from the following observations:—

1. The dejecta of a patient who had been suffering from cholera about twelve hours, and who died on the second day, presented an enormous quantity of globular masses of a dark-yellow colour, except at the centre, where the colour was much lighter, and the mass was much more transparent than at the side (Plate III, Fig. v, 1), which is not unlike the ones figured by Brittan. Strong liquor potassæ being added, one of the "cysts" burst, as at 2, and gradually broke up as at 3, 4. The semi-fibro-gelatinous mass in which the "cysts" were involved was entirely dissolved. Another slide was taken, and two cysts selected, a large one and a smaller one (Fig. vi, 1, 2); strong acetic acid being added, no result followed for some time; pressure was applied,

and the large one broke up into air-globules and granular matter (3, 4). Pressure was again applied, and the small one also broke up, as shown at 5. Another case may be quoted as illustrative of this kind of cyst. The evacuation was passed six hours after attack, and two hours before death; it contained numerous cyst-like bodies, some entire, others more or less broken up, and in many cases seemed to contain partitions (Plate III, Fig. vii). These bodies withstood the action of rectified ether until the fibro-albuminous matter surrounding them had been removed by the application of potash.

2. In the same evacuation other globular cyst-like bodies were found of a yellowish-green tint, having a more defined outline, and more evenly diffused contents (Plate III, Fig. viii, 1, 4). These were unaffected by the ether, and remained unaffected by liquor potassæ for three days. These cysts occurred in nearly all the evacuations examined, but their precise nature was for a considerable time unexplained. They were sometimes round, but generally oval, and in some cases formed about a fourth of the entire sediment. This was particularly observed in some dejecta with which I was favoured from the Medical College Hospital, obtained from a native who was admitted with all the symptoms of cholera, but eventually recovered. They were, as in other cases, of a greenish-yellow tinge, with colourless hyaline capsules, for the most part oval (x)—sometimes round, and varying considerably in size, as seen in the figure. One of these cysts was selected for special observation, the one represented at Fig. ix, 1; ether being added, the contents cleared up a little, but nothing further; this was followed by strong liquor potassæ, which caused it to become dotted and streaky, the yellow tinge, however, remaining (2); gradually changing to the appearance depicted at 3, the centre becoming more transparent than the circumference, which still further extended, as at 4. The transparency of the central portion diminished in the course of a few minutes (5), in which condition the object was left under the microscope until the next morning, when it was found to have retained its form, but had acquired a dark colour. Another cyst was selected with a dark-yellow granular centre, and hyaline capsule (Fig. x, 1). Ether was added; scarcely any change; merely clearing up the centre a little. It was then rolled over, and the granular contents spread throughout the entire cell (2). Firm pressure was applied, the eye being kept steadily at the microscope, when suddenly numerous minute molecules escaped (3), and the capsule became partly emptied of its contents (4). Liquor potassæ was added to a portion of the evacuation, and allowed to stand all night. The cysts on examination next morning appeared unaffected.

To another test tube sulphuric acid was added. The cysts, after remaining several hours in the acid, were not much altered, but presented a globular outline with a hyaline capsule surrounding a greenish-yellow molecular mass (Plate IV, Fig. xi, 1, 2). On rolling them over they became oval, but soon regained the circular form. On the addition of a strong solution of iodine, the contents became dark-brown, and on subsequently adding absolute alcohol. fat-like globules made their appearance, which, by manipulation could be made to move within the cell; the capsule being unaffected

(Plate IV, Fig. xi, 3). Alcohol being added to another cyst without the iodine, the contents assumed a lumpy appearance with a clear space in the centre (Plate IV, Fig. xi, 4).

Several very small embryos of round-worms having been observed in the evacuation in active motion (Plate III, Fig. viii, 8), diligent search was made as to their origin, which resulted in the explanation of the nature of the cysts also. The latter were frequently observed to give evidence of some kind of systematic arrangement of their contents, as shown in the figure (viii, 5, 6), and eventually a cyst was observed to contain something which rolled within it; this, after prolonged watching, was seen to present the exact form and size of the worm-like body just alluded to. It was coiled up on itself within the capsule (Fig. viii, 7), and continually altered its position. This corresponds pretty accurately with the drawing of the ovum of *Ascaris mystax* in Dr. Cobbold's work on Entozoa. It is, I think, pretty much the same as the cholera-cell of Mr. Swayne. In many cases the contents of these ova are also shrunken, occupying a part only of the enclosing membrane, as insisted on by this gentleman as a means of diagnosis. The effects of re-agents also, as above given, correspond very closely with the description given by him.

3. There is another cyst not very uncommon in choleraic dejecta, having a more delicate, but very resistent capsule (Plate IV, Fig. xii). Its nature may be inferred from the following statement: On two or three occasions, semi-disintegrated *acari* were observed in the stools examined, which had, in all probability, been swallowed with the food, in bread perhaps, and passed through the intestinal canal without being very much broken up, as may be seen from the figure (xiii). It did not, however, occur to me to connect the existence of the thin capsuled cysts with these *acari*, until one day two were seen rapidly depositing their eggs among some fungi under cultivation, which were being microscopically examined. These eggs corresponded precisely with the just described cysts.

4. Mr. Brittan figures some oblong bodies (Plate II, Fig. iii, 2), which are not reproduced in M. Robin's plates, but were probably also considered to have some connection with cholera by the author of the article in the *Medical Gazette*. These are exceedingly common, and are accurately drawn in Plate IV, Fig. xiv, where one is seen entire, and another ruptured, together with one of Mr. Swayne's bodies in a ruptured condition; both required the application of considerable pressure before the capsule gave way. The first described elongated body is, I believe, the ovum of another round-worm, the *Tricocephalus (dispar?)*. As to the cysts with distinct spore contents, which Hallier has figured (Plate I) as being a mature condition of the cysts comparable to the drawings in Robin's work, I have not met with any which were unmistakably the same in fresh dejecta, but have developed them repeatedly; the particulars will be given further on. Other cyst-like bodies are occasionally found, but as they do not in any way correspond to those of the author of the theory under consideration, a description of them is reserved for another occasion; the principal

ones, however, are those already described, namely, (1) *compound cysts*, consisting of fragments of various tissues and fat surrounded by a semi-organized fibro-albuminous layer, and (2) *ova* of various kinds, none of which are peculiar to cholera.

As, however, the ultimate elements of other cysts than these might exist in the dejecta, every known method was resorted to for the purpose of developing them, a few illustrations of which I give in a condensed form.

Illustration I.:—

Small portions of the dejecta which contained such numbers of the cysts, alluded to in page 7 and represented at Plate III, fig. v, were placed in three perfectly clean watch-glasses with the following substances:—

I.—Cholera evacuation 3 drachms, and 2 drops of acetic acid, so as to neutralize it.

II.—Cholera evacuation 3 drachms, phosphate of ammonia 3 grains, grape-sugar 3 grains.

III.—Distilled water 3 drachms, phosphate of ammonia 3 grains, grape-sugar 3 grains.

To receive these, a small wire stand had been placed in a shallow dish containing a strong solution of permanganate of potash, and the stand and watch-glasses covered in by a bell-glass (carefully cleaned, and subsequently rinsed with alcohol) which stood in the fluid. This was set aside in an average temperature of 82° *Fahr.*

On the third day small white specks were seen on the surface of No. I., which had returned to its alkaline condition, one of which was picked out as rapidly as possible from beneath the bell-glass and placed on the stage of the microscope. It consisted of an aggregation of minute molecules held together by a slimy substance, from which filaments of fungi escaped (Plate IV, Fig. xv). Thus matters stood until the fifth day, when from No. II. [a speck] being picked out, presented numerous spores (Plate V, Fig. xvii, 1), many of them germinating very actively (2), and the filaments here and there were swollen out into macroconidia (3, *m*), some of these dilatations being transparent, others granular; frequently the filaments were seen to terminate in a bulb (4), and in one case a filament was tipped by a cyst in which the contents were granular and had contracted from the capsules (5). Precisely similar filaments and dilatations were found in No. I. but a distinct cyst (or sporangium) could not be seen. This condition lasted until the seventh day, when the mycelium gradually degenerated, and a crop of aspergillus appeared on all three, of various colours, but principally of the dark varieties.

Illustration II.:—

A portion of the fluid contents of the small intestine from a patient who had died within six hours of attack was carefully transferred to a vial, and allowed to settle for an hour. In the meantime a "growing solution" was made, consisting of grape-sugar 3 grains, phosphate of ammonia 10 grains, glycerine 1 drachm, and distilled

water 1 ounce. A drop of this was placed on three glass slides; to these were added:—

No. I.—A minute quantity of the upper layer of intestinal contents.
No. II.—A minute quantity of the sediment chiefly.
No. III.—A minute quantity of diabetic urine containing "yeast-cells."

These were placed as before under a bell-glass placed in Condy's fluid; on the third day specks appeared on the preparation in each slide, which proved to be due to spores and mycelium (Plate IV, Fig. xvi), the three slides presenting similar appearances under the microscope. On the fourth day No. I. presented an excellent forest of penicillium, and No. II. a similar crop of aspergillus, of the black and purple coloured variety, while No. III. produced both penicillium and aspergillus. These were systematically examined for eight days, no other fungus making its appearance. The aspergillus crop in No. II. presented tufts of different colours; specks were observed in the other two preparations; a speck of yellow and brownish-purple being the most abundant.

To experiments conducted in this manner, there is the serious objection that each time the preparation is examined, no matter how carefully, the possibility exists of foreign matter getting into the preparation. With the intention of obviating this source of fallacy as much as possible, an isolating apparatus, in the form of an aspirator, was employed to supply the preparation with purified air, at least as pure as passing it through concentrated sulphuric acid will allow. By referring to the accompanying sketch it will be readily seen how this was effected (Plate V, Fig. xviii). A small funnel (1) with a pledget of clean cotton wool inserted into its neck was attached to a piece of bent glass-tubing; this tubing passed through a perforation in the cork of a flask (2) containing concentrated sulphuric acid; from the neck of this flask another piece of glass-tubing emerged which connected it with a perforated bell-glass, standing in a shallow dish containing Condy's fluid; (3) another piece of tubing connected this with the aspirator (4) filled with water. All the connections were carefully luted, so that the only air which could have got at the preparation on the stand within the bell-glass (of course *minus* the air which previously existed therein) must have passed through the sulphuric acid.

Illustration III.:—

A perfectly fresh choleraic evacuation having been obtained two hours before death (in a rapidly fatal case lasting only seven hours), three watch-glasses were placed in the isolating apparatus with the following ingredients:—

No. I.—A slice of the interior of a plantain weighing quarter of an ounce was scooped out, and six drops of the sediment from the evacuation were placed in the little cavity thus made.

No. II.—A few drops of the evacuation-sediment only.
No. III.—A slice of the same plantain as in No. I.

The apparatus had been made as clean as possible previous to this, rinsed out with spirit immediately before depositing these glasses on the stand beneath the bell-glass, and the greatest care taken to avoid foreign matter getting at the preparations before placing them there. The air within was renewed morning and evening; the weather was warm the whole time, the average day temperature of the room being about 90° *Fahr.*

On the fourth day a mould was seen to appear on the two slices of fruit, quite as marked on the clean plantain as on the other, but no change was visible in the watch-glass containing the evacuation only. This condition lasted a fortnight, the crop of fungus gradually increasing in the two former, and no change could be observed in the latter. During the third week, the fungus not having made any progress, and the liquid in the watch-glass No. II. becoming rather less, from evaporation, the apparatus was opened on the twenty-fourth day, and the result carefully examined forthwith.

The two pieces of fruit were covered with a thick coating of a black-and-yellow coloured fungus, both colours appearing in the two preparations; the yellow prevailing in the tainted slice, and the black on the other; the difference being merely in the proportion, for tufts of each colour appeared here and there over the surface. These were found under the microscope to be *aspergillus* (Plate VI, Fig. xix, 1) and *penicillium* (xix, 2). Precisely the same fungus and the same species grew on glycerine, on starch-paste, and on pieces of dirty cork in various parts of the room. In the other watch-glass, however, containing the evacuation only, a very different appearance was observed. The preparation had become partly dry, and presented a filmy appearance. On placing the watch-glass on the stage of the microscope, a great quantity of spherical bodies were seen with granular contents, the average size being about that of a white blood-corpuscle, but the size varied considerably, among which long delicate mycelical filaments ramified (Fig. xix, 3); from this network thin fertile threads arose, tipped in most instances with exceedingly delicate vesicles (xix, 4), which appearance at first was taken for the dewdrop aspect so common to mycelium; others were seen of a much larger size. On watching them closely, all the bodies were seen to roll round and round, like a *volvox*. Elongated (spore-like) bodies were distinctly visible within each delicate capsule, unless very small (xix, 5), and seemed to move irrespective of the capsule (or sporangium): of this, however, I am not certain. They appeared white by reflected light, and yellowish-green by transmitted light. The movement appeared to me to be due to currents of air in the room, each little sphere twirling round rapidly in one direction for ten or twenty turns, then as rapidly twirling in the opposite way. The course of the spinning vesicle was not always horizontal, but varied until it was nearly vertical to the filament on which it was perched, but never

quite vertical. It seemed analogous to the spinning of a plate or ball nicely pivoted on a juggler's stick, which may be seen to revolve in every direction but the vertical, the analogy being complete, except that the organic connection between the sporangium and the stalk rendered reverse turns necessary. On touching this with water, the capsule appeared to become instantaneously dissolved, no trace being left: the spores had fallen down, and the filament looked perfectly bare. Some parts of the mycelium were dilated into saccules (or macroconidia) (Fig. xix, 6), but no evidence of spore contents was distinguishable.

Illustration IV.:—

Being desirous of ascertaining whether from the rice-water stools in epidemic cholera I could produce capsules more unmistakably like those figured by Professor Hallier than I had succeeded in doing from discharges obtained in an endemic locality, such as Calcutta is, a sample was brought from Lucknow, carefully secured in a clean vial, which was obtained during my visit to the North-Western Provinces during the epidemic of cholera which occurred there in September 1869. A drachm of the sediment was poured into a perfectly clean watch-glass, and placed on the stage in the isolating apparatus in the manner described in the last illustration. In the course of a week a film was seen to have formed, which continued to increase in density for another week, but no trace of any mould could be observed in it through the bell-glass. At the end of three weeks the preparation was taken out and microscopically examined, but no cysts had formed, as in the former preparation treated in exactly the same way, but there was a great quantity of mycelium, in the meshes of which numerous circular bodies were embedded (Plate VII, Fig. xx); the latter seemed to be the result of segmentation of the former, judging from the similarity between the free cells, and the imperfectly detached segments of mycelium. The watch-glass was replaced in the apparatus for a fortnight, but no change took place.

From these illustrations it will be seen that whereas cysts, distinctly resembling those described by Professor Hallier, may, by *cultivation*, be observed to develop in choleraic discharges, yet they are by no means constantly obtainable, for out of more than a hundred cultivations, made with the express object of developing these cysts, only three times was I able to produce any fungi bearing such tokens of fructification.

Is it possible to develop fungi in other than cholera dejections bearing fruit resembling the "cholera cyst"? The answer must be "Yes," as the following experiment will show from cultivations of ordinary healthy stool, one isolated and the other exposed.

Illustration V.:—

About half an ounce of fæces, obtained from a perfectly healthy person, was placed on a small glass plate, and carefully transferred into the bell-glass of the

isolating appartus in connection with the aspirator, as already described, the greatest possible care having been taken to prevent foreign matter coming into contact with it before depositing it on the stage in the apparatus. A small portion of the same substance was placed on a glass slide, without any special precautionary measures being taken to prevent access of foreign matter, so as to be able to examine it from day to day for comparison with the preparation in the bell-glass, which it was not intended to disturb. On the second day a few small white spots were observed on both preparations, one of which was picked out with a needle from the non-isolated mass, and placed on the stage of the microscope. It consisted entirely of minute molecules, round and elongated (Plate VIII, Fig. xxi, 1), embedded in a white shining substance (2), in connection with which were circular and oval cells of a greenish tint (3); frequently two or more were seen strung together (4); clear spaces were seen in them all nearly.

On the fourth day the mass in the apparatus was completely coated by this white humus, except that some of the earlier observed spots had acquired a yellowish-brown colour. The exposed slide presented a somewhat similar appearance. The cells had become nearly everywhere strung together, and long filaments of *oidium lactis* (Fig. xxiii), corresponding exactly to the figures given by Thomé of the cholera fungus discovered by him, to which rather a long name was given at the time, viz., "*Cylindro-tænium Choleræ Asiaticæ.*"

This condition lasted till the sixth day, when a crop of a white mould was perceptible in the isolated preparation, and a plentiful crop of *penicillium* and *aspergillus* appeared on the other cultivation (Fig. xxii). The slide having become rather dry, a few drops of distilled water were after this occasionally added. On the eighth day long delicate filaments were seen growing out of the white humus-looking substance in the apparatus, and on the tenth day other filaments were observed, which seemed to be tipped with various coloured heads, apparently of the same kind as on the other slide, those of a bluish and yellowish-brown tint prevailing; but by the eighteenth day the long delicate filaments had grown over them, the whole surface of the preparation presenting a woolly appearance. After this no further change could be seen to take place in either cultivation, and on the twenty-first day of the experiment the bell-glass was opened, and the glass plate placed on the stage of the microscope. Precisely the same species of *aspergillus* and *penicillium* were found as existed in the non-isolated cultivations, with the addition that great numbers of the filaments forming the white flocculent tuft bore at their terminations cysts or sporangia filled with distinct spores (Plate IX, Fig. xxiv, 1-4), which, I think, correspond exactly to the cysts figured by Professor Hallier of the immature cholera-cysts, whose drawing has already been given, and may be compared with this.*

Aspergillus tufts were present in great numbers: nearly all of them had fallen

* I have obtained excellent examples of this fungus (*Mucor*) on the intestinal mucous membrane of the pig also, whilst subjecting strips of the intestine to continuous observation.

off from their filaments among the mycelium; a few, however, were perfect, consequently easily recognised. Some of these fallen masses were germinating (Plate IX, Fig. xxvii, 2), and presented, as nearly as anything possibly could, the appearance of the mass of spores figured by Professor Hallier as a "cholera-cyst" in process of germination (Plate I, 11).

As the preparation was dry, a few of the cysts were transferred to another slide and water added, upon which many of the capsules of the sporangia gradually ruptured, and the spores escaped (Plate IX, Fig. xxv), a bare columella and the ruin of the capsule alone remaining.

As it was not advisable to expose the preparation during the experiment, the various stages in the development of these cysts were not followed, in order to ascertain which some spores and cysts were sown on the juice of various fruits, boiled and unboiled, and on pieces of cheese. They rapidly germinated, and in those preparations which were sown in cells on the slide without a covering glass produced precisely similar cysts to those sown; when, however, covering glasses were used, the fructification was not so perfect. For example, a glass slide was taken, and two semi-circles of asphalt varnish were brushed on it, one being rather larger than the other, so that the ends of one half-circle might overlap the other, but not so closely as not to permit the entrance and exit of air, as may be learnt from the figure (Plate X, xxix). When nearly dry, a minute quantity of growing fluid, consisting of a solution of grape-sugar and phosphate of ammonia, was placed in the centre, upon which a few spores were sown, a thin covering glass being placed over it, which adhered to the semi-dried varnish. The slide was placed under a bell-glass, kept damp by being lined with some moist blotting-paper, at an average temperature of 90° *Fahr.*

In the course of six hours a clear oil-like spot appeared in the spores, and on the second day they were germinating rapidly (Plate X, Fig. xxviii, 1). On the third day the field was crowded with mycelial filaments (Fig. xxviii, 2), and on the seventh day a filament which had crept beyond the *droplet* of fluid into the free space between it and the varnish bore a distinct sporangium (Fig. xxviii, 3). Separate spores, however, were not distinguishable in the cyst.

These illustrations will, I think, be sufficient evidence to show—(1) that the cholera-cysts figured by Professor Hallier are not always obtainable from choleraic discharges, (2) not confined to cholera, (3) nor even to diseased conditions of the intestine, but (4) may be cultivated from the stool of perfectly healthy persons.

The experiments instituted to test the observation as to the inoculability of rice plants have as yet not been satisfactory, consequently no conclusions have been arrived at on the matter.

SECTION II.—"SPORES."

It is by no means so easy to explain what the yellowish more or less oval hyaline bodies are which Professor Hallier calls "spores" (*vide* Plate I, 3); such

bodies are exceedingly common in choleraic discharges, and I believe are very different in their nature; but whether any of them are "spores" will, I think, be satisfactorily explained in the sequel. The objects I have met with in cholera discharges more or less resembling these bodies may be arranged into four classes:—

(1)—*Globules of a fatty nature;*
(2)—*Altered blood-cells;*
(3)—*Corpuscles embedded in the tenacious substance composing the "flakes;" and,*
(4)—*Globular conditions of certain infusoria.*

1. Persons accustomed to microscopic work must have found that to distinguish fat or oil globules from other bodies very different in their nature, is not always so easy a matter as is commonly stated in text-books on the subject. It has frequently occurred during this investigation that, in spite of the addition of heat, absolute alcohol, rectified ether, potash, iodine, and other re-agents, not overlooking the prolonged application of carmine, I have failed in distinguishing with certainty fat globules from pellets of slimy substances endowed with life, when both were known to be present. Indeed, I have frequently mixed fat with gum-water and other substances for the purpose of testing the value of the re-agents which had been applied to bodies under examination, and have found that, in a great number of instances, the results are fallacious; either the globules remain unaltered, or both kinds are destroyed, or they are acted upon indiscriminately. A fair sample of this difficulty is carefully delineated at Plate XI, Fig. xxx, representing objects very like delicate "cysts" and "spores," which being watched for eight hours remained unaltered, resisting pressure, etc., but broke down in twenty-four hours into unmistakable globules of oil.

Having experienced very great difficulty in this matter, I propose giving one more example of a condition which is a particularly prominent feature in the early stools of a cholera patient; indeed, for a long time I was unable to persuade myself that it was not a condition of some low form of life, especially when the globules were highly coloured, or when the homogeneous contents of the pellicle shifted its position.

A sailor was admitted into hospital with all the symptoms of cholera, and, at the time this evacuation was obtained, suffered from severe cramps. The stool was examined three minutes after being voided, was found to be alkaline and of a muddy colour. The sediment consisted almost entirely of greenish-yellow corpuscles, varying considerably in size, the larger ones being flattened out under the covering glass (Fig. xxxi); many of these having the contents contracted, the contour of a delicate, filmy capsule being evident at the spot where shrinkin seemed to have taken place (Fig. xxxii). They were generally spherical (1), but many were oval (2), and a few were seen presenting several hyaline projections whilst rolling in the fluid on the slide (3). In some cases they retained their form and appearance for a long time, but the greater number lasted only for a few hours. They were frequently observed to vanish suddenly like a distended blood-cell, leaving only a ring behind (Fig. xxxiii, 1), previous to which,

in a few instances, a slightly granular appearance was presented (2), and the ring was often seen particularly granular (3, 4, 5), as if all the contained granules had adhered to it. The globule in the centre of the figure, with the contents separated from its enclosing pellicle (6), was watched for a long time, but no alteration in its appearance occurred. Other similar bodies were watched continuously for three hours with the same result, save that they gradually became excessively transparent, visible only by careful adjustment of the mirror. In the course of four or five hours the entire field presented the appearance delineated in the figure last alluded to. At Plate XI, Fig. xxxiv, a regular colony is seen of these globules surrounding a crystal. They also disappeared in the course of a few hours.

Rectified ether caused the pellicle to present a minute granular appearance, and those which had the contents puckered became symmetrical. Boiling in ether seemed to thicken the pellicle. A portion of this was set aside until the next day, and was found to have retained its condition, whereas the globules in the evacuation set aside in the vial had disappeared.

Absolute alcohol subsequently added to the boiled portion seemed rather to diminish their number. In some cases one globule was observed to "melt" into the other, so as to form one globule; otherwise no change was observable.

Solution of chloride of zinc and iodine,—some became shrunken and irregular, others continued spherical, but with a finely granular pellicle.

Solution of iodine only caused several of them to become very transparent—scarcely visible, were it not for the slight tint communicated to them.

Liquor potassæ causes them to lose their yellow colour; they become perfectly transparent, except that a few molecules which existed within are brought to view. A few of the globules withstand the re-agent for some time.

Acetic acid seemed to coagulate the pellicle, as it became finely granular: very much the same appearance as followed the addition of alcohol.

Dilute sulphuric acid caused the contents to contract, but the colour was retained, or it became slightly brown.

Dilute nitric and hydrochloric acids acted in the same way.

I have made many attempts artificially to produce globules of this kind, the nearest approach being a mixture of melted butter, albumen, and gum-water well shaken together, and at the time of examination adding a little thick syrup so as to cause the puckering to take place between the pellicle and the contained fat. The action of re-agents, however, on this pellicle was slightly different to the foregoing.

Spores immersed in fluids of varying density become greatly altered in their appearance; frequently the outer layer becomes so attenuated, and perhaps stained, that it is a matter of great difficulty to state positively that the cell pellicle surrounding the protoplasm of a spore differs from the clearly defined outline of a globule of oil, in spite of a knowledge of the action of re-agents, and of the varying powers of refraction which liquids manifest. Hence it is not impossible, nor inexcusable,

that Professor Hallier in some instances might have been deceived by these appearances, especially as it is evident from the conclusions he draws concerning the importance of some of the "cysts" in M. Robin's plate (which are undoubtedly fat), that he had not made prolonged microscopic examinations of ordinary excreta: the Professor, however, had more spore-like objects to deal with than fat, such as the ones described in the next and following paragraphs.

2. Almost invariably circular cells are observed in choleraic dejections of a greenish-yellow or brownish tint; contents generally homogeneous, and the capsules very delicate.

The microscopic appearance of one of these capsules is here represented at different distances from the object-glass, the size selected being about the average (Plate XII, Fig. xxxv). The appearance of the capsule a little before the focus is attained is shown at 1, a clear spot shading off into a dark ring. On bringing the object-glass nearer to it, the defined outline of a spherical body is seen with slight opacity in the centre (2); and on attaining the exact focus, a greenish-yellow perfectly hyaline sphere is brought to view (3). On going beyond this, a dark spot is seen in the centre, gradually shading off towards the periphery (4); when the light is shut off almost entirely, a slightly irregular space is seen presenting a very slight pink tint (5); this particular cell was constantly watched for three hours, when suddenly it became transparent, and required most careful illumination and focusing to make it visible, a delicate ring of a slightly diminished diameter being all that remained (6).

These, however, are not always spherical; frequently a very filmy tongue-like projection is observed (Fig. xxxvi, 1), sometimes more than one (2); it is projected exceedingly slowly, and then retracted amœba-like. After a time this action ceases, the projected vesicle-like tongue is either permanently retracted, or is left out rolling about with the corpuscle in the fluid (3). These are doubtless distended blood-cells, a great number of which may exist without yielding the slightest trace of colour to a rice-water evacuation.

Whilst following the changes taking place in these particular corpuscles in various fluids, I had opportunities of making an examination of the urine of a patient in the General Hospital under the care of Dr. Lyons, who had been suffering from the condition known as "*Chylous urine*" for about a month, together with pain in the right testicle, and great emaciation, in spite of good food and a good appetite. As the colour so closely resembled many rice-water stools, I carefully examined it, and was repaid in a way I had not anticipated. It was albuminous to the extent of about one-fourth of its bulk, slightly acid, with a specific gravity of 1·015; ether caused a separation into two layers, a clear urine-like fluid containing oil molecules, and a white homogeneous mass consisting of minutely molecular *débris*. Before the addition of re-agents the fluid under the microscope so closely resembled the condition of a cholera stool just described, as not to be distinguishable from it; yellowish-green

cells, some hyaline, some granular, some protruding a tongue-like prominence, and others with the contained plasma puckered in various ways (Plate XII, Fig. xxxvii). A few of the larger corpuscles were seen to shift themselves (like an amœba) a distance fully their own diameter, the shape altering at the same time. At first I doubted that they really were blood-cells, as the extent of variation in size was considerable, as shown by reference to the figure, which is carefully drawn to scale. The fluid very quickly gelatinised in the test tube; indeed it frequently does so in the patient's bladder, giving rise to stoppages during micturition. I have not seen cholera discharges spontaneously gelatinise, although such a condition is said to occur. A portion of the coagulated mass (which when stirred closely resembled a lump of moist gluten) was teased on a slide with needles and examined. It consisted of fibrillæ studded with blood; granular cells, scarcely differing from those seen in cholera discharge flakes, except, perhaps, in being more universally granular. They seemed to present more of the character of pus-cells.

In the midst of this fibro-albuminous matter several *embryos of a Round-worm* were discovered every time the urine was examined, one of which is seen coiled up in the drawing (Fig. xxxviii). A careful sketch of a larger one, after the addition of acetic acid, is given at Fig. xxxix. In the course of a few minutes, when the sketch was nearly completed, a *caudal-bursa* became visible under the influence of the acid, and is delineated at No. 2.

When first seen, I thought there were some detached filaments of a fungus, judging from the hyaline, structureless appearance presented; after a time, however, a few of them were observed to move very slowly, when all doubt as to their nature was at an end. It will not be surprising that the existence of these was not suspected, when we consider that fully two hundred of the larger size figured could pass abreast through a very small pinhole, an orifice not exceeding the fiftieth of an inch in diameter, as may be verified by a simple calculation.

Perhaps this fact may help to throw some light on a very obscure disease, of which little is known beyond the symptoms, although frequently met with in some parts of the world; and, indeed, may perhaps account for its localisation to such places as the west coast of Africa, where I am told it is by no means a rare malady.

As the mature worm still retains a hold on its victim, being perhaps safely lodged in the kidney, and not having seen an embryo of this kind before, nor yet a drawing, I must leave to a more experienced helminthologist to decide to what species of nematode it belongs.*

3. In examination of this class of corpuscle, namely, those intimately associated with the well-known flakes in cholera dejections, it is of the greatest importance that the evacuation should be a recent one, because its character may be entirely changed in the

* While this report was passing through the press, the "*chylous*" condition which this urine had presented for more than two months gradually disappeared, and so did all traces of albumen, and of the embryo-worms.

course of an hour or two. Sometimes, however, the change is not so rapid, depending on the chemical nature of the fluid, especially on the extent of its alkalinity—cholera stools being most invariably alkaline. The method adopted in these examinations is to pour the discharge into a conical vessel, set it aside for a short time, and, when the sediment is seen to have been deposited, a pipette is introduced in order to transfer a portion of it to the slide. Frequently the sediment is seen to be of a very slimy nature, requiring some tact in bringing it into the pipette.

Illustration I.:—

The evacuation was from a man suffering for eight hours from a severe form of cholera, who died on the second day. It was of a pale straw colour, with a muco-flocculent deposit. In the upper liquid portion nothing special was visible, but on examination of the sediment, it was found to consist of flakes of a gelatinous semi-fibrous texture, studded with globules, circular and oval, with a pale yellow tint, and of a homogeneous nature, a very correct representation of which is given in Plate XIII, Fig. xl. In some of these bodies a clear space is observed, but nothing further could be made of their nature.

Iodine stained some of a brownish-red, and others of a deep yellow.

Liquor potassæ seemed to make the corpuscles more distinct at first, and to isolate the contained granules and molecules, giving the contents a distinctly dotted appearance. The fibrillated substance became slightly granular, then it gradually faded, and so did the corpuscles, which in the course of half an hour entirely disappeared, except here and there a little cluster of molecules, five or six, with a clear space in the centre, all trace of the fibrillated texture having disappeared.

Acetic acid increases the stringy appearance at first, making each little fibril appear dotted like a very fine bead of granules, or minute molecules; eventually the fibrillated appearance is obliterated altogether, a diffused, finely granular substance being universal. The corpuscles maintain a sharply defined outline; the continuity of the outline, however, seems frequently somewhat broken in one or two places, as if the circle were formed of two or three short vibriones imperfectly united at their ends. The next day the sediment was still slimy, and could not be taken up by means of a delicately pointed pipette. It still consisted of a streaky semi-membranaceous substance, but the imbedded cells had either become transparent, or presented a granular or minutely molecular appearance (Fig. xli), with no distinct cell wall. Solution of chloride of gold picked them out very distinctly.

On the third day the flakes had lost their membranaceous character altogether, but many of the granular corpuscles remained. On the fourth day a few animalculæ were seen, which enormously increased by the fifth (Fig. xlii). On three occasions only have I observed the appearance of *this* protozoon in choleraic discharges.

Several evacuations from the same patient were subsequently examined; the flakes, however, did not present the fat globule-like appearance again, but molecular, as shown in the previous Figure (xli).

Illustration II.:—

Another case, the third liquid stool, presented a yellow colour, about one-sixth of which was composed of a whitish flocculent sediment, in which the corpuscles were granular when the evacuation was voided, and exhibited amœboid movements. The sediment presented precisely the same microscopical character as the second stage of the last described; a semi-membranaceous substance, dotted with irregularly defined cells (Plate XIII, Fig. xliii), very like what is seen in exudations effused in catarrh. On very careful watching they are seen to protrude excessively delicate processes of an amœboid character (Fig. xliv), just as the white blood-corpuscles do.

Liquor potassæ caused the membranaceous appearance to vanish after a time, reducing the cells to an aggregation of granular or molecular particles. *Ether* does not destroy them, nor does *acetic acid*, but it seemed to make manifest a delicate cell wall; and *iodine* superadded enhanced this appearance, in many cases causing the contents to collect at one part of the cell (Fig. xlv).

The membranaceous appearance had disappeared in the fluid on the fourth day, but the granular cells remained visible for nearly a week.

Illustration III.:—

The fifth evacuation of a patient suffering from the cold stage of cholera was examined half an hour after it was passed. It was colourless, with a few shreddy flocculi floating in it. It was slightly alkaline. The flakes presented the same membranaceous appearance as in the foregoing example (Fig. xliii), with numerous corpuscles, more or less intimately held in the meshes of this texture, a great number, however, being dispersed in the fluid; some were oil-like and some granular, examples of both kinds being spherical and oval, and the gradations from the merest particle of slimy or oily matter to the complete corpuscle were so fine, that it was impossible to point out any salient distinguishing character about them. When free, the hyaline and granular corpuscles were more or less round, but when contained in the meshes of this fibrillated texture, were generally elongated, as shown in the drawing (Plate XIV, Fig. xlvi).

Iodine solution being added to the slide, it was observed that whereas some of them were coloured brownish-red, the greater portion became merely stained by the ordinary tint of the iodine (Fig. xlvii); all, however, in the course of the day becoming granular, but the distinction of brown-red and mere yellow remained.

In the course of an hour other slides were prepared, but the microscopic appearance had become totally different. The oil-like bodies, of whatever shape, had become granular, and the field presented exactly the same appearance as presented in Plate XIII, Figs xli and xliii, while the addition of re-agents produced the same results. On the fourth day all traces of corpuscles had passed away, merely broken down molecular matter remaining.

4. Intermixed with the corpuscles already described are others to which I wish to allude with the greatest caution. Frequently a globule has been observed for some

time, and finally disposed of as being merely an oil one, when suddenly it is seen to protrude a portion of its substance; retract it, and while so doing another protrusion becomes visible at some other portion of the little mass, and then, perhaps, it will shift its position, exactly after the manner of an amœba.

These are frequently hyaline in a fresh stool, but generally granular; no trace of nucleus or contractile vesicle can be observed; sometimes they are very numerous, but when there are other corpuscles in the field which act in a somewhat similar manner, it is impossible to say to which class they belong, unless, indeed, they move across the field like an ordinary amœba, and not merely content themselves with protruding portions of their substance into the surrounding fluid, as was stated the corpuscles in the last described kind did. I am not in a position to state that these are the "still" and amœboid conditions of more than one kind of animalculæ; probably they are, but that they are so of one kind, I think I may state pretty definitely; and, as they are sometimes distinguishable in the still globular condition for a considerable time, they really may have been the bodies seen by Professor Hallier, and mistaken by him for swollen spores; most frequently, however, they are of short duration.

The cause of this variableness I am not in a position to state.

These bodies were noticed very early in the course of the inquiry, and every particular concerning them noted; but I have to confess that not a few links are wanting in the "life history" of these animalculæ, which the following illustrations will but too plainly demonstrate.

Illustration I.:—

A pale, straw-coloured, perfectly liquid stool, in which the sediment was very scanty, was obtained from a patient in the cold stage of cholera. The dejections being passed involuntarily, numerous little heaps of *sarcinæ* were present (Plate XIV, Fig. xlviii), as indeed exist to a greater or less extent in nearly all the cholera evacuations examined, with numerous masses of a granular or jelly-like substance, in which yellow translucent lumps are imbedded, probably of a fatty nature (Fig. xlix 1); together with masses of a somewhat similar outline observed to alter in form very slowly, as at 2. In some cases a pellicle becomes evident, when the contained jelly-like protoplasm contracts, as at 3, the various forms assumed by which are represented at Fig. l, with a great number of more or less spherical bodies very like oil globules (Fig. li.); some are seen to be flattened out (1), others protruding a vesicle exceedingly slowly; the body at No. 2 becoming in the course of five minutes to the condition delineated at 3, 4, 5; whilst great numbers of a minute animalculæ were seen actively moving among them all; sometimes one flagellum is seen a posterior one, at others an anterior one also, both being retractile at will, and another may be darted forth out of any portion of its body. No organized structure can be seen, neither mouth nor

eye spot, nor any trace of contractile vesicle, merely a spindle-shaped speck of jelly enclosed in a delicate elastic sac, endowed with the power of rapidly altering its shape and position (Plate XV, Fig. lii). So capable are they of adapting themselves to circumstances as to be able to insinuate themselves with the fluid through the meshes of fine blotting-paper. All these were present to a greater or less extent for a week.

A drop of the fluid was placed on a hermetically sealed slide, and the little bodies remained active until the fourth day, when they gradually ceased to present any kind of motion, but settled down into irregular little masses of jelly-like appearance, to which condition also the corpuscular bodies had been reduced (Fig. liii). On several occasions, however, the animalculæ were seen to become more than usually active for a short time, before ceasing altogether: to push out processes in all directions, and as quickly taking them in again, finally settling down as shapeless little pellets. Some of the various forms assumed by *one* of these at this stage are sketched in Fig. liv.

Illustration II.:—

A condition precisely similar to the foregoing was observed in the evacuation of another man a few hours before death, as well as in the contents of the large and small intestine at the *post-mortem* examination. The action of re-agents is much the same as on any other hyaline protein globule.

They remained unaffected by strong *acetic acid* for ten minutes; gradually, however, the contents contracted more or less regularly, thus allowing of a delicate capsule being brought to view (Fig. lv, 1). After a time the contents vanished, merely a finely granular ring being left (2); *absolute alcohol* made the contents appear granular, as at 3, whilst some appeared but little affected; *ether* subsequently being added caused them to shrink considerably, but did not dissolve them (4).

Iodine stains them a brownish-red, and makes them appear somewhat granular (5).

In order to test whether some of them might not be "spores," a series of observations was commenced, some of which have already been described in the chapter on "Cysts" (page 6).

A growing cell was prepared on the Rev. Mr. Berkeley's plan, by drawing a ring of varnish on the glass slide, allowing it to become nearly dry, cleansing it, as well as the covering glass, thoroughly with spirit and distilled water. A *droplet* of the evacuation was then transferred to the centre of the cell (Fig. lvi), care having been taken that no part of the sides was touched by the fluid when the covering glass was applied.

It was afterwards hermetically sealed, sufficient air being already enclosed to allow at least of germination. The limited area of the preparation enabled the geography of various objects to be easily remembered, and tended very materially to precise observation.

On the second day the corpuscular bodies appeared to be more granular or less like oil globules, frequently with one or more indistinctly visible vacuolæ (Plate XVI, Fig. lvii, 1); many are elongated, and presenting very slight movements (lvii, 2). A few animalculæ were still present; germinating spores were also visible.

On the third day the circular and oval bodies had almost entirely disappeared, but on approaching the margin of the fluid immense numbers of the animalculæ, to the extent of half the field of the microscope, were seen moving about with great rapidity, and perpetually altering their form, a clear space being observed in some of them (Fig. lvii, 3).

On the fourth day the activity of the little animalculæ had diminished, many were gradually re-assuming the circular condition. Thinking that this was an indication for a fresh supply of air, the varnish was scratched away from a small portion of the side with a needle, watching the effect under the microscope while doing so. They did not appear to be particularly affected by this proceeding, for in the course of an hour they had all become circular, and almost motionless; many attempts were made to get at a more complete life history than this, but hitherto without success.

The duration of the corpuscles and of the active animalculæ is very variable, sometimes easily recognized in stools which have been kept for a month; on other occasions disappear in a few hours. They have frequently been seen, after having been thoroughly dried, to re-assume active movements on the addition of fluid; but exposure to the sun at a temperature of 120° *Fahr.* stops all movements, no matter in what fluid they are placed, becoming sometimes completely disintegrated, but they will re-appear in such a fluid after a time under favourable circumstances—probably new ones being developed. These bodies are not confined to any particular stage of cholera, as the following will prove.

Illustration III.:—

The dejection of a person, shortly after the first symptoms of cholera set in, was obtained for examination. It was about the third liquid stool, of a pale yellow colour, slightly alkaline to test-paper, with the average amount of sediment. This consisted almost entirely of circular corpuscles presenting amœboid alterations of shape, associated with blood-cells and animalculæ, the bodies sketched in Figs. lviii to lx, Plate XVI. *First*, a number of large granular cells, very delicate filmy spheres, rolling about under the covering glass (Fig. lviii.) frequently, as if undergoing the process of division; *secondly*, corpuscles of the same granular appearance, but generally somewhat smaller, from which filmy, vesicle-like projections were seen to proceed very, very slowly, and as slowly retracted, followed by a similar protrusion from another portion of its substance (Fig. lix, 1), or two or more may be seen at the same time (2). The granular and minutely molecular matter did not enter into these saccules, and

I am not certain whether an inner or an outer wall exists, but sometimes it seemed very like as if the outer gave way for a filmy inner lining to come forth (3), at other times it seemed quite the reverse (4). After a short time the projections in many cases appeared no longer to be retracted, and were seen to curve upon the cell as the evaporating fluid bore it along (5). Some, however, are seen to be of larger size (6). *Thirdly*, blood-cells which have assumed very peculiar outlines, the result of *diosmosis* (7); and *fourthly*, innumerable animalculæ, of the kind already alluded to, exhibiting great activity amongst the various cells in the field (8).

The patient died on the next day, but a stool was examined a few minutes before death; it was highly coloured with blood, and contained a great number of animalculæ (Plate XVI, Fig. lx). Some of these were tugging at the blood-cells and altering their form, distinctly pulling the pellicle or cell envelope away from the enclosed plasma. No. 1 was altered to 2, 3, and 4 in the manner described and shown in the figure. The animalculæ presented an unusual appearance; either a large clear space existed in most of them, of the same size as the blood-cells, or one or two blood-cells had become engulphed in their homogeneous substance. In some cases they were distinctly seen to be merely adherent, the little creature rushing along as if it had no burden.

The next day the blood-cells had become granular, but the animalculæ were as plentiful as ever, and continued so for a fortnight, everything else having broken down.

Having now given a brief account of these few classes of corpuscular bodies, and shown that none of them were seen to germinate like the spores of fungi, the question naturally arises—Are any of them peculiar to cholera?

The *first* class, namely, those of a fatty nature, need not be considered, for no one will suppose them to be peculiar to the disease; the same may be said concerning the presence of blood, and as to the shape assumed by its corpuscles, the figure already given in connection with "chylous urine" will show that there is nothing peculiar about it, nor yet about the amœba-like movements of the blood-corpuscles, as the following easily repeated little experiment will show.

A small portion of a slightly alkaline cholera evacuation was filtered off into a test tube, and having pricked my finger, a few drops of blood were allowed to fall into the fluid, with which it was immediately mixed, and a drop of the mixture transferred on a slide to the microscope; nearly all the red cells were seen to present a stellate or ecchinnulate appearance (Fig. lxi, 1); only a few white corpuscles were visible, and these presented a granular, more or less circular outline (2). Some, however, were spread out like an amœba (3), but no movements were seen. In the course of two hours the stellate form of the red cells had disappeared, and presented the various forms commonly seen in evacuations (4). Having been unable to see any of the white cells protrude portions of their substance, it occurred to me that, perhaps, the temperature of the fluid being only 80°, was the cause; consequently another portion of the fluid was filtered and carefully warmed up to 110°, when a drop or

two of freshly drawn blood was introduced. This time a very slightly granular white cell was seen to alter its form and protrude one or two vesicles from its substance (5), and draw them in again, which it continued to do for a few minutes, then ceased, becoming more granular than it was before. Others were observed to act in the same way; one pale white cell was seen to possess a very delicate filmy capsule, extending some distance beyond the contents (6); it suddenly vanished altogether, leaving a merely irregular granular heap to mark its position.

The *fourth* class (it will be more convenient to consider the third afterwards), namely, the various stages of the animalculæ, was for a considerable time the subject of much curiosity, especially the kind described as presenting such activity. The fact of their being almost universally present in choleraic dejecta, and yet never, as far as I know, alluded to, except indeed that Thiersch of Erlangen could have seen one of these on the point of passing into the "still" condition, during which stage pseudopodia are incessantly projected in all directions, when he speaks of having observed actinophrys-like bodies in some choleraic dejecta which he had examined, and wondered what they were.* There was some difficulty in tracing this body to any of the described species of animalculæ. Its minute and rapid motien added to the difficulty, as well as the variableness of its shape, because although generally spindle-shaped, it may become round, triangular, or stellate in less than a second; frequently a succession of pseudopodia are seen projected in a wave-like manner, as if lashing the fluid when about to pass out of the active state. It is generally hyaline, but may be granular; sometimes a vacuole is observed, but a contractile one never. There is always a very delicate posterior filament, at first continuous with the sarcode, and a still more delicate anterior one, both retractile.

In some respects it agrees with the description of the Monad *Bodo*, but as Cienkowski, in his celebrated article in Schulze's "Archiv," distinctly states that in the amœbiform stage of all the true monads the *pseudopodia* are pointed, whilst in the amœbiform stage of this animalcule the projections are, I think, invariably rounded, so that for this and other reasons, which need not be entered into here, room may probably be found for them among the Astasiæa or Euglenæa family, so common in our tanks. The association of a cholera entozoon with the euglena, one species of which, when in its mature condition, causes the red colour observed in so many pools, and which Ehrenburg thought was the means by which the miracle was brought about of turning the waters of Egypt into blood,—the finding of precisely similar animalculæ in drains, gave rise, as may be supposed, to not a few very pretty theories, which, I regret to say, like many others, had to be abandoned altogether.

* The animalculæ alluded to in this Report do not in any way resemble the figures of the actinophrys-like protozoa accompanying Dr. Sanderson's account of his celebrated experiments published in Mr. Simon's Ninth Report.

A gentleman, with whose personal habits I am well acquainted, suddenly felt some griping pains with inclination to go to stool, but was otherwise perfectly healthy. The motion was very scanty and very diluted, but was followed by immediate relief. It occurred to me to subject the stool to a microscopic examination, and, to my surprise, these animalculæ, both in the active and "still" stages, were present in the most perfect condition, together with numerous globules of a fatty nature, exactly similar to those already alluded to. A comparison of the figures here given (Plate XVI, Figs. lxii-iii) with ones previously described will, I think, be sufficient without repeating that description.

The next stool passed by this individual was also a relaxed one, and microscopically of the same character, after which the motions were perfectly natural; but, in proportion as the motions became more solid, the ease with which these animalculæ could be found diminished. Many other ordinary evacuations were examined, and in fully half, after more or less careful search, they were discovered. After a brisk purgative they are frequently seen in great perfection.

In alluding to the nature of the *third* class of bodies, namely, those found in the meshes of the fibrillated substance composing the flakes in cholera evacuation, I wish to premise that the remarks are reservedly made, as the subject belongs more directly to the pathological anatomy of cholera, which subject forms a later part of the programme drawn out for guidance in connection with this inquiry. It will, of course, be understood that the corpuscles of the former three classes are also found with the corpuscles forming this division; indeed, it is frequently impossible to separate them, especially from those amœbiform conditions of animalculæ which are seen so frequently in evacuations. This is probably the reason why so many different descriptions exist of their appearance and of the action of re-agents.

Now, the chief statement I have to make concerning the corpuscles of this class is that they *exhibit movements somewhat like the movements associated with the amœba.* This fact may, by very careful examination with a good $\frac{1}{8}$th of an inch object-glass, be verified by any one accustomed to the use of the microscope in most cholera stools when perfectly fresh. A portion of the substance of the corpuscle is seen to creep out insensibly from the mass, and as insensibly return: unless the eye is carefully fixed on the body, and is already a more or less educated eye, the phenomenon is not detected, and the observer enters it as "disintegrated epithelium" in his note-book. It may perhaps be remarked that no drawing of columnar epithelium, said to be so universal in cholera dejecta, appears in this report. The reason is that its presence, to an appreciable extent, has not been observed in the contents of the intestines discharged during life; indeed, the only occasions on which I have been able to observe it quite distinctly were in discharges voided a few minutes before death, a long interval having elapsed since the occurrence of a previous stool. It was Boehm, I think, who first laid

great stress on the fact of the shedding of the epithelium in cholera about 1832, since which period it has been the general opinion in Germany, with the exception of Virchow and a few others. In the well-known Bavarian report of 1857 I find great prominence given to this view, modified, however, by the remark that, as a rule, only the broken down epithelium, or rather freed nuclei of such, are seen. Dr. Beale also lays great stress on the diseased condition of the epithelium, and the latest authority on the subject, Dr. Macnamara, follows Dr. Beale; indeed, it is evident that Dr. Macnamara's explanation of many of the phenomena observed in this disease is based upon a conviction of the correctness of the views advanced by these writers. It is of the utmost importance in matters of this kind, as was pointed out by Professor Parkes in 1848, not to confound the microscopical appearance of the rice-water stools passed during life with that of the contents of the intestine obtained after death. In a *brochure* which was published by him on this subject at the time I find stated:—"With regard even to the separation of the epithelium, although from the facility with which this structure is shed, even during ordinary healthy processes, it does appear probable, *à priori*, that it would be largely thrown off in cholera, *there is absolutely no proof that it is so thrown off until after the death of the patient. The stools contain none, or a quantity not more considerable than is present in common diarrhœa.*"* Judging from the cholera stools which have come under my observation in Calcutta,—several hundred specimens,—I believe that not more than two out of twenty slides will contain distinct traces of columnar epithelium.

That these corpuscles are the remains of diseased epithelium may, I think, be disproved without any reference to *post-mortem* appearances, which I wish at present to avoid; *first*, by the fact that, under favourable circumstances, they *exhibit movements exactly analogous to those seen in the blood, pus, lymph, chyle, and the so-called "mucus" corpuscles. Secondly*, cell formations and minute flocculi, microscopically identical with these, may frequently be observed under other conditions, and from sources where it would be difficult to account for their presence were they epithelium fragments, such as in the fluid obtained by pricking a blistered surface. *Thirdly*, that even where portions of columnar epithelium are seen they will, I believe, almost invariably exhibit, no matter how much broken down the cell appears, the delicate rim or basement membrane lining the free end of the cell, believed by some to be pores communicating with the cells. The presence of epithelial fragments, when not excessive, may be readily accounted for by the process of renewal which takes place in all cells. Dr. Sharpey writes:—"The particles of columnar epithelium are undoubtedly subject to shedding and renovation. According to Donders and Kölliker, the columnar cells on the villi appear occasionally to cast off parts from their upper ends, with subsequent reparation of the loss; that is, a cell enlarging, and a second nucleus appearing; the upper and broader part with its nucleus and much of the cell contents separates, and the lower remaining portion with its nucleus grows again to the natural size." And, *fourthly*, the epithelium thus discovered in the dejecta will

* The italics are mine.

remain for weeks unchanged in the fluid in which it was found, showing that the action of the liquid portion of the stool is not so destructive to it as would be inferred if the numberless corpuscles seen were the result of the disintegration of epithelium which had been shed. I think there is no doubt but that these are the "peculiar corpuscles" first described by Dr. Parkes, which probably the circular, "still" condition of the animalculæ alluded to in this report, the microscopic appearance and the action of reagents coincide so entirely with the minute description given of them in the author's work. I am as yet not in a position to verify the author's belief that they are confined to any particular stage of the disease. I hope, however, to obtain more exact data on the subject in my next report.

With respect to the nature or origin of these corpuscles and the fibrillated substance in which they are imbedded, I have not been able to disprove, nor in any way to modify, the views expressed by the writer at the time when he drew attention to them in the following extract, which may appropriately serve as the concluding sentence of this paragraph :—

"It is in the highest degree probable that they owe their origin to effused blood-plasma, which assumes with great rapidity a low, ill-defined, and non-progressive organization."

SECTION III.—"MICROCOCCUS."

The term "micrococcus" (*mikros* small, and *kokhos* kernel) is now pretty generally adopted on the continent by the class of writers who advocate the pre-existence of a GERM, in some shape or other, to every living thing, this germ, which may be infinitely minute, being called its "micrococcus;" whereas another class of writers, very numerous now in England as well as on the continent, maintain that the pre-existence of a germ is not necessary to the development of living objects, providing certain atmospheric, chemical, physical, and other agencies are present; the nature of the object developed depending on the relative proportion of these agencies or "forces." In short, that life is a creature of circumstances, those circumstances being of an entirely physical nature. The question of the existence or non-existence of a "germ" being of such great importance in connection with epidemics and infectious diseases generally, and its investigation associated with so many difficulties, I should have preferred not alluding to the subject of this section at present, not having had time to accumulate sufficient material to enable me even to obtain a clear idea as to what changes take place, much less to attempt passing any opinion concerning those changes. As, however, it might be thought that no attention had been given to this portion of Hallier's theory,—in some respects the most important, and certainly the most difficult to disprove,—a few illustrations will be given of what has been done in the matter.

As already explained, the micrococcus, or germ of *cholera*, is, in the opinion of Hallier, the disintegrated spores of a special fungus, which escaping into water may be swallowed, or after being wafted by the air, adding a trifle to the "dust," according to Professor Tyndall, so prevalent therein, reach the interior of the human body, there to develop at

the expense of the nitrogenous material, notably the epithelium of the intestinal canal.

It will, of course, be evident that the attempts, already described, to produce a peculiar fungus by cultivation of choleraic discharges in which bodies somewhat resembling "cysts" and "spores" existed, equally favourable conditions were at hand for the development of their ultimate elements;—seeing, however, that the fungi which then appeared possessed no peculiarity, one may conclude that either the attempts to cause the development of the particular micrococcus of cholera were failures, or that no cholera "micrococcus" existed, at least not as the germs of a fungus.

During the earlier part of the inquiry it was thought that a greater number of minute bodies of an organic nature existed in cholera stools than were found elsewhere; to this impression the mind was evidently, though unconsciously, predisposed, from the fact that the fermentation theories of cholera, necessitated, to a more or less extent, the supposition that monads,* bacteria, and vibriones (Plate XVII, Fig. lxiv) flourish to a greater extent in this than in other diseases. Thus far I have not found this to be the case; indeed, the discharges of cholera patients, if examined immediately, do not contain such quantities of these minute bodies, especially if the stools have been voided in rapid succession, consequently have not been long detained in the intestinal canal. Neither have I been able, after repeated observations, to find that, during the decomposition of a cholera discharge, a greater number of the minute bodies associated with putrefaction were developed in it than were developed under similar circumstances, such as the amount of heat and moisture in ordinary alvine discharges; nor have I been able to find that any peculiar growth, animal or vegetable, will proceed from the one which does not proceed from the other. On this point, however, the number of observations have been far too few—the sources of fallacy being so many—to enable one to speak with confidence, but I trust in the next report to be able to furnish more minute data concerning this matter. On an average, out of a dozen experiments undertaken, not more than one is brought to a satisfactory conclusion, which is not to be wondered at, when it is considered that the quantity of matter experimented upon does not exceed one-fourth the size of a drop of water; that this requires the free admission of atmospheric air, and that it has to be examined at least daily, for a month or more, often for hours together. Either the fluid suddenly evaporates, or the lens touches the covering glass, thus disturbing the geography of the preparation; or, which is the most frequent accident of all, and one of the most untoward, a minute spore of some fungus falls from the air upon the moist slide—germinates; the filament insinuates itself through the little air-orifice which had been made in the walls of the growing cells, and reaches the preparation, where it not only obscures the field, but alters the chemical and other forces taking place in that *droplet*, and the forms of life which had

* Irrespective of any theory as to the nature or mode of formation of these minute bodies, I have followed the example of Professor Hughes Bennett in adopting the terms "monads" when simple molecules are meant (Fig. lxiv-1); "bacteria" when the bodies are slightly elongated (2); "vibriones" when still more so; and "leptothrix" when presenting a linked appearance (4).

developed therein—I do *not* say spontaneously—become altered also. I have frequently observed that a slight disturbance affects the development of these minute organisms; either the forms of life previously present cease to grow, being replaced by others, or the vital process becomes changed, and the manifestations of life take another direction.

These points will become more or less evident from a perusal of the following examples, which are intended to serve as illustrations of the method adopted in carrying out these investigations, rather than as evidence for or against any particular hypothesis.

In order to be the better able to judge of the significance of the development which might take place in substances obtained from diseased conditions, it was considered of the utmost importance that definite knowledge should be acquired of what developed in nitrogenous material, when it was known that no disease existed. With this object in view, solutions were made of various substances, to which choleraic and other discharges were added, careful notes and drawings being made of the changes that occurred from day to day.

Illustration I.:—

As examples of the changes which occur in solutions of ordinary organic matter, the following experiments on watery infusions and decoctions of meat are selected on account of the simplicity of the mixture, and as illustrative of what has been stated above, namely, that slight alterations in their surroundings exert a powerful influence on the forms which living matter will assume.

(*a*) One ounce of carefully filtered, distilled water was placed in a test tube, and a piece of raw meat (beef) about the size of a pea dropped into it, the portion being carefully removed from the centre of a fresh piece of muscle.

In the course of twenty-four hours the upper half presented a milky appearance, and there was a very thin film on the surface. It consisted of minute molecules (monads or micrococcus), together with long linked filaments of a larger size than vibriones, which were perfectly still (Plate XVII, Fig. lxv). The milkiness of the fluid continued to increase, but the pellicle did not get much stronger, for on the third day, whilst attempting to remove a little, it broke altogether and sank in the fluid. On examination it was found to contain a few long filaments with monads and short vibriones, among which little oval accumulations or "heaps" were seen, as if composed of broken down molecules (Fig. lxvi). The next day the vibriones were considerably longer, but no other change was visible (Fig. lxvii). On the fifth day the "heaps" had increased in number; although they appear granular with a power of three hundred, they are distinctly seen to be molecules by a higher power, such as Ross' $\frac{1}{8}$th of an inch object-glass, except the central portion, which seems to be of an amorphous nature, and reflects the light differently. In contact with the particle of meat was a shreddy substance, also containing heaps, in the midst of which

round cells of various sizes had developed, from a minute molecule, presenting a brighter appearance than the ones in the field generally, up to cells with a diameter somewhat greater than that of a red blood-corpuscle (Plate XVII, Fig. lxviii). The larger ones were seen to be surrounded by a distinct capsule, between which and the contained protoplasm (which had a bluish tint) a little fluid seemed to intervene; this in certain lights presented a red tint. The hyaline substance altered its shape occasionally within its capsule, but the movement was an exceedingly slow one. In the cells a few grades smaller than the ones described, the protoplasm presented a somewhat bluish tint, but of a yellowish-blue when exactly in focus; they also seemed to possess the power of altering their form, or rather to dilate and contract very slowly.

These molecules kept increasing in number and size. As a rule, the larger they are, the more amorphous matter surrounds them; that is, the larger the heap. After this putrefaction set in very rapidly; no further progress occurred, but the whole became disintegrated.

(*b*) A small portion of meat was placed in distilled water as above, and thoroughly boiled for some time in a Florence flask; filtered whilst hot into a clean test tube (which had been previously subjected to the flame of a spirit-lamp); it was then covered, but not so tightly as to prevent the entrance of air, and placed in the same compartment as the foregoing.

On the second day it had become milky, and presented a slight film of a somewhat similar nature to the previous one; little chains (leptothrix) interspersed throughout the field, with a few monads and short vibriones. This appearance was still more marked on the third day (Fig. lxix). On the fourth day the linked filaments were present, but the molecules (or micrococci) had increased in size, which, with the short vibriones, presented great activity. On the fifth day the milky appearance had diminished, but no change could be observed under the microscope.

Little "heaps" now formed amongst the molecules, the fluid at the same time clearing up, and towards the end of the third week the slight precipitate which it contained not only presented monads, bacteria, and vibriones, but animalculæ in great numbers, which were seen at one moment elongated and very active, the next circular and still (Plate XVIII, Fig. lxx), very like the ones above described as occurring in choleraic and other discharges. In some of these, however, one, two, or three contractile vacuolæ were observed lasting about three seconds, and about three seconds absent. In addition to these, a few amœbæ were present, with no contractile vesicle; probably an earlier stage. It was then set aside for a fortnight; the animalculæ were, if anything, more plentiful than before, and when in the active or "still" condition were not distinguishable from the ones described as being found in the stools, as may be seen by reference to Fig. lxxi, where, in addition, some green-coloured cells are seen. The latter were not observed to develop into anything higher, although watched carefully on a slide for two months; they simply increased in size and in number. The

test tube was set aside for another fortnight, and was found to contain larger animalculæ than before, belonging to the Kolpoda family; no cilia could be made out, but a contractile vacuole was very evident. The various stages in the life history of these animalculæ will be minutely described further on, in connection with other observations.

At the end of the third month cilia were easily demonstrable. The animalcule very closely corresponds to the *Paramecium Kolpoda* of authors.

(*c*) A portion of the boiled solution of meat used at (*b*) was placed in another test tube, filtered with a perforated cork, in which was introduced a piece of glass-tubing bent a little more than at right angles; one end was dipped into the fluid in the tube, and the other was drawn out to a very fine point, but not perfectly closed up. This was devised with the intention of ascertaining whether expired air would produce any alteration in the forms of life which might subsequently become manifest in the decoction, as a preliminary to future experiments on organisms developed in crowded and empty rooms. With this view, the test tube was breathed into once or twice daily for a fortnight, then set aside in order that a film might have an opportunity of forming.

At the end of three months the cork and glass-tubing were removed. A delicate film had formed, which on being touched sank to the bottom of the tube. The fluid was clear, free from smell, and presented no organisms when examined microscopically. A portion of the subsided film was removed by means of a pipette. It consisted of minute molecules and filaments held together by a slimy substance. Imbedded in the midst of these were a great number of yellow globules, microscopically not distinguishable from globules of oil. The appearance presented by the field is carefully delineated at Plate XVIII, Fig. lxxii. They were unaffected by liquor potassæ, iodine, and dilute acids for some time; eventually, however, more or less granular contents became evident; no organic connection could be seen to exist between the globules and the filaments, and no animalcule of any family was present.

A small portion of the film was placed upon a growing slide, and a drop of the solution of grape-sugar and phosphate of ammonia added to it, so as to ascertain whether they were spores of a fungus or the "still" condition of one of the infusoria.

The particular growing slide used was the one devised by Dr. Maddox,—by far the best cell with which I am acquainted for purposes of this kind. A strip of tinfoil is cut into two ∪-shaped pieces, one being larger than the other, so that when the smaller is placed upside down ∩, it will fit loosely inside the upright portion of the other. These are stuck in this position on a glass slide with a little varnish, over which a thin covering glass is so fixed that the only air or foreign matter which can reach the preparation must pass up the "chimney" thus formed between the inner margin of the larger strip of the tinfoil and the outer one of the smaller, as will be readily seen by referring to Fig. lxxv.

On the third day the globules were seen to have increased considerably in number, and on the eighth day germination was rapidly taking place (Plate XVIII, Fig. lxxiii).

A little gum-water being added caused the central part to become clear and watery, and the protoplasm to shrink in the mycelium (Fig. lxxiv). Germination continued for a few days longer, but no more advance stage could be attained.

(*d*) A test tube containing the water used in these observations was also set aside, but nothing developed in it.

Illustration II. :—

About a drachm of ordinary fæces was dissolved in an ounce of distilled water and filtered, a portion of which was placed in a watch-glass and boiled thoroughly; a drop of this was afterwards placed in an ordinary animalculæ growing slide, both being set aside under a bell-glass.

On the second day monads and vibriones were present in great numbers in both preparations, but on the third day they had greatly diminished in number in the watch-glass, in which, however, during the night several young animalculæ belonging to the Kolpoda family (as figured at Plate XIX, lxxx) had made their appearance.

In the live-box, however, vibriones only were present as before, some of them being very long, but no Kolpodæ. On the fourth day great numbers of amœboid bodies, varying considerably in size (Plate XIX, Fig. lxxvi, 1), multiplying very rapidly, sometimes by leaving small fragments of their substance behind (2); the portion escaping invariably from a part near the contractile vesicle, which vesicle remained bright for fifteen seconds, became puffed out suddenly, as though it had been a taper, and remained extinguished for the same period, then gradually shone again. The detached portion (3) seemed not to be merely disgorged food, for it crept about the field like its parent; it also divided into two, pretty symmetrical, halves. For some time after the commencement of division, the "nucleus" is only seen in one half (4) after considerable tugging, then coming together, then separating again, each time getting a little more detached, until in the course of about two minutes the separation is complete. Frequently a mass of granules is seen to intervene, probably indigestible particles, which may adhere to either half (5), but is soon cast off, and gradually a contractile vacuole is seen to appear in the second half, which creeping along the field draws particles into its substance, and acts in every way like its parent (6).

On the fifth day the fluid in the slide having somewhat evaporated, a little distilled water was added, when suddenly the hitherto more or less oval amœbæ (Fig. lxxvii, 1) commenced protruding and retracting exceedingly long processes (2), which action lasted three-quarters of an hour. They then became circular and still, except that the vacuole contracted (3). In another half hour some of them commenced to creep along the field, disgorge themselves, leaving a string of granules to mark their path (Fig. lxxviii, 1); others were observed in the course of another half hour to become circular, with a clear halo-like ring surrounding them (2), their contents being in very active motion, reminding

one exceedingly of corn in a miller's hopper. This lasted for twenty minutes, when suddenly all movements ceased; the halo and vacuole disappeared, its outline became irregular and undefined (2, 3); finally, although the eye was constantly observing it, all trace disappeared, and no distinction could be observed between other molecules in the field. The remaining amœbæ seem to have undergone the same change, for when the eye was removed from the particular one described, none could be found, except a few empty-looking ones. I have frequently observed exactly similar phenomena occur in the so-called salivary corpuscles. No further change occurred in the slide, nor was there a return to the former condition during the succeeding week.

In the watch-glass the animalculæ continued to increase and multiply, but other kinds did not appear. The glass was held over a spirit-lamp and the liquid boiled, in order to see if out of their dead bodies others of the same or of another kind would appear; but none did, and at the end of a fortnight the experiment was brought to a close.

Illustration III.:—

The ordinary stool, to which allusion was made at page 27 as containing such quantities of the animalculæ in the "still" and active condition, was kept under observation for six weeks.

A slide was taken and two minute portions were placed side by side, a distance of about half an inch intervening, and circular covering glasses applied of the same diameter.

During the first, second, and third days the changes which occurred were alike in the two preparations. The oil globules gradually disappeared, the circular, "still" condition of the animalculæ became at first granular, ceased presenting the amœboid projections, the latter being frequently not retracted, but trailed along as they rolled under the glass; the general appearance of the altered slide being represented at Plate XVI, Fig. lxiii, the earlier condition having already been described, and is figured at lxii.

The movements of the active little entozoon became more and more sluggish; at the same time it became granular and circular, and finally disappeared altogether, probably passing into the "still" condition, which also gradually disappeared. The two preparations now assumed different appearances.

(*a*) On the fifth day some fungi were seen to develop in one of the preparations, which may be designated—*a;* long filaments of oidium lactis, as figured at xxiii, commenced spreading over the entire preparation, and in the midst of the molecules (which had also undergone various stages, as already described in the first illustration) little "heaps" were forming of precisely the same microscopical characters as are given at page 32 and other places. On the sixth day a few molecules in the midst of the heap had increased in size, and on the eighth day nearly every heap was covered with yeast cells, in conjunction with very minute anguillulæ (?) (Plate XIX, Fig. lxxix).

The oidium lactis disappeared entirely in the course of a few days, but no other changes took place for a month, except that the yeast cells degenerated also.

(*b*) The portion under the other covering glass showed no evidence of fungal development, nor yet yeast cells or anguillulæ. On the sixth day accumulations of perfectly motionless molecules had formed, especially near the edge of the glass, each heap possessing, as usual, a kind of central kernel with a more or less protoplasmic appearance; the molecules forming the peripheral part of the heap being quite as active as the molecules elsewhere. On the seventh day these heaps were crowded with cells of all sizes. Some of the molecules were larger than formerly; the greater number of the cells, however, were from about the size of a red blood-corpuscle to four times that size; the contents of the larger ones being more distinctly molecular than that of the smaller, otherwise no difference could be established between them. It is, however, particularly to be noted that the steps from the minute molecules to the smaller sized corpuscles were by no means so gradual; it did not appear as if a sufficient number of molecules of the intervening grades existed to enable one to say that the large corpuscle was simply a developed molecule. On many occasions great pains were taken in order to try and settle this question, but each time, although after the formation of heaps molecules have been seen to become, so to speak, swollen, suddenly little corpuscles appeared with undefined outline twice or three times the size of the molecules, and in a few hours the field is crowded with animalculæ. The difficulty of ascertaining this point is due to the *suddenness* with which these changes take place. After watching a certain little heap for several hours without any appreciable alteration having occurred, the eye becoming tired, it is allowed to stand unobserved for an hour or two. On returning, probably everything is changed; either the particular heap watched has become altered, or some other heap in the preparation has been more advanced, and discharged the elements of life which it contained, and these animalculæ rushing about the field knock the watched little heap over, disturbing its entire geography. This is precisely what occurred in the preparation now under notice. It had been watched all day in order to ascertain whether the swollen molecules would swell still more in the course of the day, but they did not, or (2) whether some of them would coalesce and form one ovum, as believed by Dr. Bennett; neither did I see this, nor could I learn that the half slimy-looking kernel surrounded by molecules had acquired a clear "nucleus" and formed *one* body, as advocated by Pouchet, for no appreciable change occurred during those twelve hours. But when examined on the next morning, twelve hours after, a great number of corpuscles of cysts were present in the midst of these "heaps," and several, what seemed to be young *paramecia*, rushed about in all directions (Plate XIX, Fig. lxxx). Whatever it was that had taken place, it did not seem to me that one heap had given rise to only one cyst, because three, four, or more of various sizes would be seen on the surface, or what seemed to be the surface of a heap (1). I am ignorant as to what occurred between the

stage of molecular aggregation and the development of the smaller-sized cysts. A few of the after changes, however, were more easily followed. A slow rolling kind of motion commences in the mass of granules, in the midst of which a clear space or vacuole becomes more and more distinct (2), at first non-contractile, then it suddenly goes out and does not return for two or three minutes: gradually these intervals become shortened: contraction and dilatation occurred pretty regularly at intervals of fifteen seconds. In a few hours it commences to spin like a top without in the least altering its position. Then it stops, its nucleus becomes extinguished, and the body appears pretty much as it did at first. After a shorter or longer period the action recommences, and eventually it becomes elongated, gets out of the heap into the fluid, and rushes about as if locomotion were nothing new to it. No cilia can be seen, nor any trace of nucleus, merely a contractile vesicle at the broader posterior end, with granules and molecules universally distributed (3). In those parts of the field where the fluid is rather thick, it creeps along something after the manner of an amœba (4). On the next day, the eighth, several were seen to move very slowly, and to become circular and still. They became surrounded by a clear hyaline capsule, and the vacuole again disappeared. A few hours after this the field presented the appearance shown at Plate XIX, Fig. lxxxi. Some were perfectly still, and had no contractile vacuole; in others the molecular contents showed active movements, with or without a vacuole; in some two vacuoles were visible, not contracting simultaneously, and in such cases there seemed to be two centres of movement—two irregular masses seemed to move within the cyst. The evidence of division was frequently more marked, a regular line of separation existing, and in others two oval bodies are seen to revolve within the capsule. In the drawing the remains of two cysts are also evident. In order to know exactly the phenomena associated with the escape of the animalculæ, the pair delineated at Plate XX, Fig. lxxxii, 1, were selected and continuously watched.

The escape out of the cyst commenced by a rolling movement among the molecules of the smaller one, which increased, until at last each molecule seemed to dance past the other. The vacuole went and came rapidly, lasting about six seconds, and in the course of another six seconds returned, then became perfectly still; movement recommenced and stopped in the same way. Thus it acted for some time; each time, however, the outline of the contents became more evident, and the cyst became more and more distended, finally ruptured (2), and the body rolled out. It was evidently not yet free, and its outline was indistinct. Very active movements were now set up, pseudopoda pushed out in every direction, and it was seen to be still surrounded by a very delicate sac. By continually turning itself about, this film became much distended, and so transparent that its form was distinctly visible (3). At last the pellicle became so attenuated that it escaped without trouble (4). The same process takes place when the animalcule has divided into two or four.

In the encysting process which follows, the cysts seem to become thicker, and a little fluid is frequently seen between the inner lining of the cyst and the delicate

sac * which surrounds the animalculæ. Frequently such cysts are seen to have become ruptured some time before the escape of the contents (Plate XX, Fig. lxxxiii, 1), and it not seldom happens that the latter after its escape does not rupture the thin inner capsule (2), but remains perfectly quiet for two or three hours. Old cysts persist for some days after being forsaken by the infusoria (3), and not infrequently the latter has left a few granules to mark its former abode (4); two or three may also develop in these thicker kinds of cysts. The size of the cyst bears no positive relation to the number of bodies it may contain; a comparatively small cyst may contain four embryos, allowing of active movements, as existed in the one delineated at 5.

At the end of a month numbers were seen distinctly ciliated; a nucleus became developed, as well as a contractile vacuole, and a current was established at the anterior portion of its body, so that particles were drawn towards it (6).

Illustration IV.:—

The fresh dejection of a cholera patient was examined almost immediately. The sediment was found to be composed of a slimy substance dotted with granules and molecules, intermixed with a great number of more or less circular bodies, some hyaline, some granular, many of which appeared to me to be the still condition of animalculæ, as already alluded to, together with several euglena-like bodies, disporting themselves in the more fluid part of the field. A careful sketch of these objects is given at Fig. lxxxiv. There were plenty of monads and bacteria in the field, but the vibriones were exceedingly small and short.

A solution of carmine in glycerine after prolonged action seemed to stain everything in the field to the same extent; the varying density of the colour seemed to depend entirely on the thickness of the layer; that is, a larger amount of colouring matter was present when the layer was thick (Fig. lxxxv).

(*a*) A minute quantity of this stool was placed in the Maddox growing slide already described, page 33. During the first two days the objects became more and more disintegrated, until on the third day not a trace existed of the circular bodies and animalculæ previously existing.

On the fourth day a few creamy-looking spots were seen at the edge of the preparation, consisting of innumerable molecules (monads) manifesting very *great activity*, together with some short vibriones.

This condition had increased greatly by the next day, the creamy appearance having extended to the entire margin of the fluid, to the extent indicated by the dark outline of the preparation in the figure of the Maddox slide at Plate XVII, lxxv.

In the midst of these molecules little *heaps* were seen to form, in which no motion was evident, nor yet any definite structure, but amorphous granules, around

* This, according to some writers, is the "cyst," outside which is the "cell," surrounded by the hyaline gelatinous "veil."—(*schleier.*)

which, and above and below, myriads of monads and short vibriones played. Some slight distance from the margin an opaque line, consisting of unusually active monads, was seen separating the creamy ring into an inner and outer portion, but no distinction could be observed between the appearance of the molecules of one side from that of the other, except that in the outer the *heaps* were more plentiful.

The monads, etc., in the central clear space had become perfectly still, and no *heaps* had formed amongst them; towards evening the line seemed to have spread on either side, as the whole creamy ring became as thickly studded with molecules—consequently opaque—as the narrow line was in the morning. The circular cells seem to have disappeared altogether.

On the sixth day not a single molecule quivered. The creaminess of the margin had slightly diminished, but the "heaps" were still present, rather more slimy-looking, not so regularly circular, but frequently elongated and straggling. The diameter of some of the molecules in contact with the mass had increased.

A mycelial filament was now seen to insinuate itself from without into the preparation, having crept up the "chimney" of the growing slide, and the further development in or about the heaps came to a standstill, although watched for a month. The mycelium spread in every direction, and gave rise to yeast cells.

(*b*) A similar slide containing a drop of this stool, to which a little of the growing solution of grape-sugar and phosphates was added, went through the same stages as the foregoing, and developed into *penicillium*, as in Plate VI, Fig. xix, 2.

(*c*) A portion of the same preparation without a covering glass was preserved in a moist chamber. On the third day a white speck was seen in the surface consisting of innumerable "yeast" cells (Plate XX, Fig. lxxxvi), with some filaments branching in all directions. On the fourth day tufts of *penicillium* had developed —two varieties (Plate XXI, Fig. lxxxviii)—*P. Glaucum* (1), and *P. Viride* (2). This continued until the ninth day, when a few of the filaments springing up in the midst of the *penicillium* were tipped with a dewdrop-like dilatation excessively delicate—a mere distended pellicle. In some cases they seemed to be derived from the same filament as others bearing the ordinary branching spores of *penicillium*, but of this I could not be positive. This kind of fructification increased rapidly, and on the fourteenth day *spores* had undoubtedly developed within the pellicle (Plate XX, Fig. lxxxvii), just as had been observed in a previous cultivation (page 12), precisely similar revolving movements being also manifested. The reaction of the liquid portion in the cell was slightly acid, and became very much more so in the course of a month. No further change took place, except that the capsules became rather thicker, but never so resistant as to withstand the action of a drop of water, spores being instantaneously set free by it.

In not a few cases a chain of spores, or sometimes delicate filaments, seemed to escape from these cysts, as if the spores within had germinated; which indeed must have been the case, unless they had fallen from a tuft of penicillium and

adhered to the capsule. In other cases dilatations (macroconidia) appeared in the filaments, and even from these a chain of spores was occasionally seen (Plate XXI, Fig. lxxxix).*

(*d*) A small portion of the evacuation was placed on an ordinary slide with a covering glass. It went through the same process as was described in connection with Maddox's slide (*a*), and eventually yeast cells were produced as at Plate XX, Fig. lxxxvi, but nothing further.

(*e*) A similar slide placed in the same moist chamber presented similar changes as the foregoing for the first four days. It was not examined on the fifth, but when placed under the microscope on the sixth day, representatives of the *kolpoda* family, both active and encysted, had made their appearance in great abundance; the various stages in their subsequent development corresponding precisely with what has already been described in connection with experiments on ordinary excreta.

Serous fluid, blood, and urine, from persons affected with cholera, as well as from other persons, have been in like manner subjected to systematic and continuous observations, the air in some of the experiments having been made to pass through a red-hot tube before its entrance into the chamber in which substances under examination had been placed, as adopted by Professor Tyndall, in order to destroy the minute *atomes* of organic matter which, according to this gentleman's researches, will pass through sulphuric acid or caustic potash undestroyed. The particulars of these observations are reserved for the present, the results being such that no benefit could be attained by giving them in detail. It is nevertheless hoped that the foregoing illustrations will sufficiently explain the methods adopted in investigating the subject of this section. The description of the changes which occurred during the cultivations has been condensed as much as possible; more so than would be allowable were they intended to establish any particular fact.

A not unimportant lesson is, however, conveyed by even the comparatively few experiments which have been conducted, namely, that, in spite of more than ordinary care, very different forms of life will make their appearance in substances which are derived from the same sources under conditions which *seem* to be identical, and that too in very simple mixtures. Consequently, the greatest caution must be exercised in estimating the importance or otherwise of any peculiar manifestations of vitality which may be observed in substances associated with disease.

The results of the investigations referred to in this report may be thus summarised:—

1. That no "cysts" exist in choleraic discharges which are not found under other conditions;

* In connection with the appearance of this mucor-like fructification in such intimate connection with penicillium on this and on other occasions, although merely an approach to the "cholera fungus" of Hallier —a fructification resembling it much more closely, if not identical with it, having been obtained under like circumstances from ordinary excreta—it must be allowed that it speaks very strongly in favour of the view so firmly advocated by this mycologist of a generic connection between *penicillium* and *mucor*.

2. That cysts or "sporangia" of fungi are but very rarely found under any circumstances in alvine discharges;

3. That no special fungus has been developed in cholera stools, the fungus described by Hallier being certainly not confined to such stools;

4. That the still and active conditions of the observed animalculæ are not peculiar to this disease, but may be developed in nitrogenous material even outside the body;

5. That the flakes and corpuscles in rice-water stools do not consist of epithelium, nor of its *débris*, but that their formation appears to depend upon the effusion of blood-plasma; and that the "peculiar bodies" of Parkes found therewith correspond very closely in their microscopic and chemical characters, as well as in their manifestations of vitality, to the corpuscles which are known to form in such fluid; these are generally, to a greater or less degree, associated with blood-cells, even when the presence of such is not suspected, especially as the disease tends towards a fatal termination, when the latter have been frequently seen to replace the former altogether; and

6. That no sufficient evidence exists for considering that vibriones, and suchlike organisms, prevail to a greater extent in the discharges from persons affected with cholera, than in the discharges of other persons, diseased or healthy; but that the vibriones, bacteria, and monads (micrococcus) may not be *peculiar in their nature*, for these *do* vary, may not be the product of a peculiar combination of circumstances, and able to give origin to peculiar phenomena in a predisposed person, is "not proven."

In bringing this part of the report to a close, I wish to express my sincere thanks to Dr. John Murray, Inspector General of Hospitals, Indian Medical Department, who has, week by week, watched the progress of these experiments, and given such practical advice and assistance as his long study of the subject particularly enables him to do. I also desire to tender my thanks to Dr. Brougham of the Presidency General Hospital, and to Dr. Baillie of the Chandney Hospital for the facilities which were placed at my disposal for obtaining the *matériel* requisite for these examinations; as well as to Dr. Norman Chevers, Principal of the Medical College, for permission to make use of his private library, as well as the library attached to the College.

II. REMARKS REGARDING THE SOIL, ETC., OF CERTAIN PLACES IN RELATION TO PETTENKOFER'S THEORY OF THE CONNECTION OF CHOLERA WITH THE VARIATION IN THE LEVEL OF THE SUBSOIL WATER.

SEEING that Professor Pettenkofer's observations extend over a period of sixteen years, during which constant observations have been taken by him of the water-level in various parts of Munich and elsewhere, it will be at once evident that the short period which has elapsed since the commencement of this investigation in India cannot

enable one to have formed but most indefinite conclusions on the subject. Accustomed as the Bavarian Health Officer has been for many years to much deep thinking on the subject, it is frequently difficult for less trained intellects to follow his exact meaning on all points, as the theory is by no means so simple that "he who runs may read."

During the last year a work* was issued by him embodying the result of the labours of previous years, in which the views already advanced are maintained with even a greater conviction of their truth than before.

The main points in Pettenkofer's theory are—(1) there exists a specific cholera poison, which (2) reaching the soil undergoes various stages of development, providing (3) that a certain amount of moisture is present; (4) should the ground not possess the requisite amount of moisture, be either too dry or too wet when the poison is placed therein, the latter will retain its vigour until the requisite conditions return; but (5) these having returned, it does not follow that an epidemic will forthwith break out, unless (6) certain meteorological conditions are present (the precise nature of which is unknown), and especially there must be (7) a predisposition to the disease in persons coming within the area in which the poison is found.

The reason why the period when cholera usually breaks out in the Upper Provinces does not correspond with the period in which it is at its height in Calcutta and in Lower Bengal generally, is, according to Dr. Pettenkofer, due to the fact that in the former place the ground for the greater part of the year is too dry, there being no rain, and the water being commonly many feet from the surface; whereas in Lower Bengal when the rains set in cholera ceases—the ground becomes too wet. Cholera is worst in the latter when the water-level is at its lowest, namely, about April; whereas in the former cholera is at its worst when the water-level is rising or about subsiding (August and September), so that, I presume, the Munich Professor would explain the reason why cholera is endemic in Bengal, and only epidemic in the Upper Provinces by the fact that the wet season is much shorter in its duration than the dry, consequently the conditions necessary for the development of the poison occur only during short periods, whereas the same conditions affect Lower Bengal in a different way, giving rise to short periods of exemption, instead of the short periods of attack, consequently the inhabitants of the "Ditch" are more exempt from cholera when it overflows with water.

It must also be borne in mind that the local fall of rain is not in all cases the only cause of variation in the height of subsoil water, for an adjoining river may rise or fall, irrespective of local conditions, and perhaps give rise to an alteration in the amount of moisture present in the soil. In a great number of instances, however, the level of the water in a well adjoining a river is considerably above that of the river, as a non-porous, clayey layer may dip towards it, thus confining the water to its bed.

* "Boden und Grundwasser in ihren beziehungen zu Cholera und Typhus." Von Max v. Pettenkofer. München, 1869.

Again, heavy falls of rain on distant hills may affect the level of the water in the plains, should an impermeable stratum extend from the one to the other, over which water might flow. These and many other such facts connected with the geology and the topography of a place must be carefully considered before any opinion can be formed of the correctness of the views advanced by this distinguished professor.

It will be seen from the foregoing that the poison is considered not to *develop* in water, which is contrary to the commonly received opinion, nor does it multiply to an appreciable extent in the intestinal canal, the human body being merely the *stage* upon which this actor plays its part. The poison requires a special *nidus* in which to multiply and to develop into infecting matter. This Pettenkofer traces to the soil, especially to alluvial soil, which, being so exceedingly porous, allows free interchange between the air in its interstices and the air above, as well as being subject to a great variation in the amount of water which it contains.

Whilst marking out on a map the places suffering from cholera, he was particularly struck with the predisposition it semed to manifest for following the natural water-courses of the country, rather than the usual routes of traffic. In the former, the places of attack were pretty regularly situated, whilst along the roads for intercommunication, the affected places show great irregularity, cholera spreading only in those parts in which the soil was of an alluvial nature, although quite as many opportunities existed for the dissemination of the poison by means of intercourse in the places never attacked as in the less fortunate localities.

The cholera-germ, as described by Pettenkofer, may be defined as a specific *leaven*, requiring earth, consisting of organic matter and salts, with a certain amount of water for its development to infectious matter, just as other ferments require certain special substrata and moisture before it manifests its action. If ordinary leaven be added to sand no action takes place; if it be added to dry flour, it does not spread beyond the immediate vicinity in which it was placed; but if the flour be moistened "the little leaven leaveneth the whole."

The question naturally occurs—By what means does it get into the human body after being thus developed in the earth? To this Pettenkofer replies: There are two ways by which substances may arise from the ground, even from a great depth :—

By means of (1) the water, and by means of (2) the air contained in its interstices.

Numerous illustrations may be produced of the possibility of substances, perceptible to the olfactory nerve, making their way upwards from considerable depths, such as when a sewer bursts, or an escape occurs in a gaspipe. Frequently this fact is not observed where the mischief has taken place, but in a house, perhaps, some distance from it, the warmth of which, should it not stand on an impervious layer, attracts the disengaged matter like a chimney, and the house acts as an escape-pipe for a noxious gas. Were it ever conclusively shown that cholera depended upon some

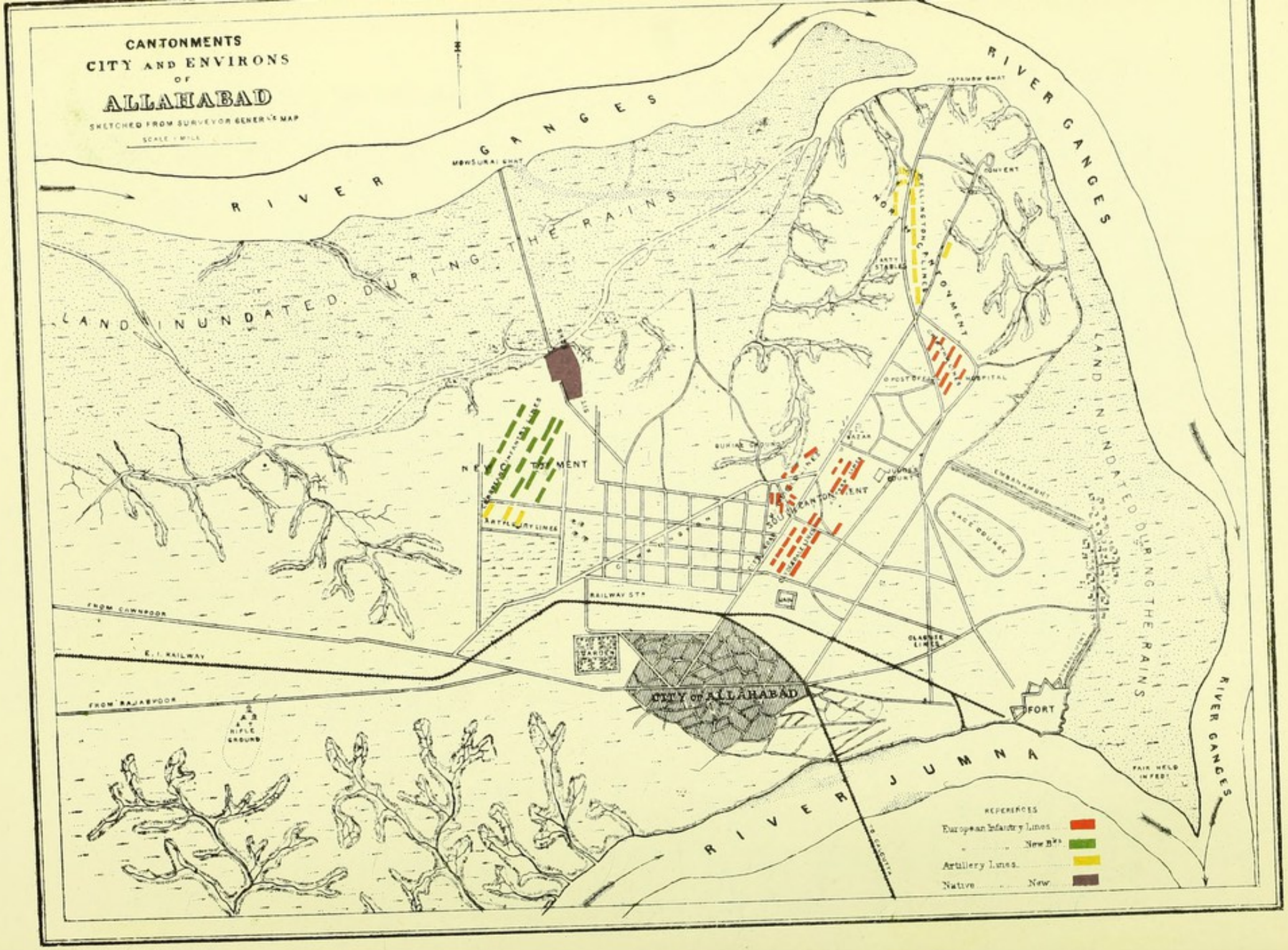
fermenting process taking place in the ground, which had been originated by some of the poisonous material being placed in a soil adapted for its development, it would follow that in India large substantial buildings would be safest by day, being cooler than it is without; but unless the flooring were made impervious to air, it would be the most unfavourable at night, being warmer, consequently the native's hut, approximating more closely to the temperature of the air ought to be more exempt from cholera.

Although cholera is not considered to acquire its property of infection by being developed in water, still water as well as air may act as a vehicle conveying the infectious matter from the ground, consequently this theory in no way affects the importance to be attached to the value of obtaining water from a pure source; indeed it speaks very strongly in favour of obtaining it from places as far removed as possible from human habitations.

Particular attention has been drawn to this subject very lately * by Dr. Buchanan, one of the several distinguished sanitary officers whom Mr. Simon has gathered around him at the Public Health Department of the Privy Council. While allowing that there is a connection between the disease and the level of the water in the wells, Dr. Buchanan maintains that the mischief *is in the well itself;* because "it is precisely at the period when soil water is sinking that wells sunk in a porous soil must, if ever, furnish impure supplies. A well in porous soil gets its water in two ways; water stands in it up to the level of the soil, and also drains into it from every source (from rain, from slops, from cesspools) on a higher level than that of the water of the soil for many yards around. In other words, besides receiving water from the general waterflow through the soil, it receives the local soil water, soaking from a cone of ground of which the surface of water in the well is the apex. Let the level of water in the soil be high, and the base of this cone is small; let the level of the soil water be low, and the base of this cone (at the surface of the ground) is large. In either case the saturated soil is comparatively impervious to more water, and approaches the condition of a non-porous stratum. When the soil water is at its highest, therefore, impure slops and excrement that may be on or in the ground tend to run horizontally away. When the soil water on the contrary is low, such matters tend to soak downwards."

It will be observed that Dr. Buchanan testifies to the matter-of-fact portion of Pettenkofer's statement, namely, the connection of certain diseases with the level of the soil water, but explains this connection in a different way. Buchanan produces very remarkable illustrations in proof of his statements, which will certainly be borne in mind whilst investigating this subject in India. The possibility of the foregoing being the true explanation of the connection between cholera and the level of the soil water had not escaped Pettenkofer, as he states that examinations have been

* *Medical Times and Gazette*, 1870.



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made of the quality of water which is sinking, and the results were by no means unfavourable—in some cases the water was even found to be more pure. As far as the tanks in Calcutta are concerned, I cannot bear testimony to the observations of Pettenkofer in this matter, because the percentage of organic matter has been greater when the tanks were low than when in the contrary condition; concerning the quality of water in deep wells at various heights, I possess no data.

The foregoing remarks will, I trust, be found to present a tolerably clear exposition of the theory concerning the relation said to exist between the spread of cholera and the state of the ground water.

I now proceed, in as few words as possible, to give an account of my visit to the places affected with cholera in the North-Western Provinces during the severe epidemic of last autumn (1869).

ALLAHABAD.

I arrived at Allahabad towards the end of August, 1869, in accordance with the instructions I had received, in order to accompany the Sanitary Commissioner with the Government of India in his tour through the cholera-affected districts, and thus be able to avail myself of his advice and direction.

Seeing that our visits to the various places, to be hereafter alluded to, were necessarily of short duration, it was impossible for me to obtain more than a very superficial knowledge of the geography of a place extending over such a wide area as Allahabad does.

Situated in the angle formed by the junction of two rivers, the Ganges and Jumna, it was thought not improbable that the high or low condition of these rivers might materially affect the level of water in the wells, seeing that many acres of land are swamped during the rains, the station being almost surrounded by water, as a glance at the accompanying map will show.

This, however, was ascertained by Dr. Bow not to be the case, at least as far as the Jumna was concerned, the water in the wells being nearly thirty feet below the level of the surface of the Jumna.

The average depth of the wells from the surface, as examined by Dr. Chalmers and myself, was found to be from fifty to sixty-five feet. The average variation in the level of the water between the dry and the wet season is about ten feet, whereas the Jumna varies to the extent of thirty feet or more under ordinary circumstances; nor does the alteration in the water-level of the one correspond with the variation in the other, and a consecutive fall of rain of twelve inches will not raise the level of the water to the extent of more than one or two; a great portion, doubtless, finding its way into the river before getting into wells, especially after the first falls of rain, when the ground does not permit of such free percolation. It cannot, therefore, be said that the amount of subsoil water at Allahabad is materially affected by the rivers which bound it on either side; nor will it be safe to judge

of the extent of moisture present in the subsoil by the registration of the well water alone; the *rainfall* must also be taken into account, as the latter at Allahabad appears to influence the condition of the soil more than the permanent subsoil water.

The soil here is of a sandy, clayey nature, intermixed with layers of kunkur.

In the hot weather extensive fissures are to be observed everywhere in the ground extending to great depths, and exceedingly permeable to water. On subsequent examination, it was found, when dried in the sun, to be solid to the extent of one-half, the other half being interstices filled with air.

In order to have a more precise knowledge of the extent of the porosity of the soil upon which the various barracks have been built, and which are said to vary in the degree of their liability to cholera, although in other respects apparently as like one another as it is possible for buildings to be, and the sojourners therein subject to precisely the same influences as regards food, clothing and water, it was thought that perhaps some clue could be obtained by ascertaining the extent to which the soil beneath the buildings was permeable to the air below. General Travers, V.C., immediately permitted samples of this soil to be obtained, which on my return to Calcutta were subjected to the following treatment:—A little of it was reduced to moderately fine powder in a mortar and placed in the sun until thoroughly dry. In the meanwhile, two *burettes* were fixed on to a stand, the lower portion or point of one being connected to that of the other by means of a piece of india-rubber tubing supplied with a clip, so as to be able at will to interrupt the connection between the two tubes. A given quantity of soil (100 cubic centimeters) was carefully placed in one *burette*, and a similar amount of water in the other. The latter was allowed to flow into the former, which, as it ascended in the tube containing the soil, was seen to drive out the air existing in the interstices, the amount of air displaced corresponding to the amount of water which entered. When the water came up to the upper edge of the soil in the tube, the connection between the tubes was interrupted, and the amount of water used read off.

As a few of the particulars of these observations may be useful for comparison when more exact data shall have been obtained of the relative liability of the barracks in question to cholera, I append them in a tabulated form:—

	Soil at a depth of 4 feet from	Amount of *air* contained in 100 parts by measure.	Permanganate solution required to give a permanent tint to a solution of 1 oz. soil, 10 ozs. water requiring 4 decems of the same solution.
ALLAHABAD.	Clydesdale Lines, No. 8, south end	50·	5 decems
	„ „ „ 8, north „	46·4	4 do.
	„ „ „ 3, south „	53·3	8 do.
	„ „ „ 3, north „	50·	...
	Chatham Lines, No. 8	50·	5 decems
	Artillery Lines, No. 2	50·	4 do.
	Wellington Lines	46·4	6 do.
	New Cantonment Barrack, No. 3	46·4	4 do.
	Jail	53·3	5 do.

Six of the specimens were subjected to chemical examination with the view of ascertaining whether the soil near the barracks, at or about three feet from the surface, contained an unusual amount of organic matter or not. One ounce of soil was taken and allowed to stand for twelve hours in pure water, shaking it a few times during this interval; it was then filtered, and the clear solution examined in the manner usually adopted for the examination of water.

The results were pretty much the same in all cases; except in those where the soil had been a "made" one, the amount of lime-salts varied, but I was surprised to find that the soluble organic matter, as estimated by a standard solution of *permanganate of potash*, did not much exceed the amount present in the ordinary drinking water of Calcutta when estimated by the same solution. (The exact relative amount of organic matter present may be ascertained by reference to the foregoing table.)

From these observations, therefore, I infer that in the ground beneath and about the barracks at Allahabad, both in the old *and* new cantonments, the amount of oxidisable matter was not in excess, at a comparatively short distance from the surface, at the time when cholera visited that station; consequently the epidemic could not have been owing to putrefying matter in the soil of the cantonments, unless such matter had been washed into the wells by the rain, and thus infected nearly a hundred and fifty persons belonging to the European troops stationed there. To have produced this, the amount of surface pollution present before the rains set in must, I should imagine, have been very extensive indeed.

It was also thought desirable that a few samples of the earth should be taken and moistened with water in order to ascertain whether any special form of life, animal or vegetable, would make its appearance. I select two examples. A small portion of dry earth from the new cantonment was placed in a test tube, to which a little water was added, sufficient to cover it. During the first and second days no particular forms of life were observed, but on the third and succeeding days several minute infusoria had become revived, and presented exceedingly active movements (Plate XXII, Fig. xc).

A similar portion of soil from the Clydesdale Lines was treated in the same way. In it also no particular objects were manifest for the first two or three days, but towards the end of a week, in addition to the objects delineated in the last figure, bodies in the circular, still, and active condition—not in any way distinguishable from the animalculæ already described as occurring in choleraic and other discharges—were seen to have developed in great numbers, some freely moving in the fluid, and others imbedded in granular matter (Fig. xci). Nothing further was observed in any of the samples, nor could I detect any evidence of the existence of the ultimate elements of fungi.

I also accompanied the Sanitary Commissioner to the "cholera-camps" occupied by the 58th Regiment, about fifty miles from Allahabad, on the Jubbulpore road; and Dr. Chalmers, the Deputy Inspector General of Hospitals, very kindly undertook to show me nearly every part of the city and cantonment. To Dr. Irving also

I am indebted for similar help. These excursions were undertaken more with the intention of getting a fair insight into the geography of the place, than of ascertaining what the exact sanitary arrangements were,—to report upon which not being the object of my visit. Careful notes, however, have been taken of what was seen and heard concerning the outbreak of the epidemic, but their narration would unnecessarily prolong this report and answer no good purpose. I hope, however, on a future occasion to turn what I then learnt to account.

CAWNPORE.

On the way to Lucknow a few days were spent at Cawnpore. Compared to Allahabad, the troops in this station had suffered very little. Dr. Bryden states that the admissions were twenty-seven and the deaths seventeen.

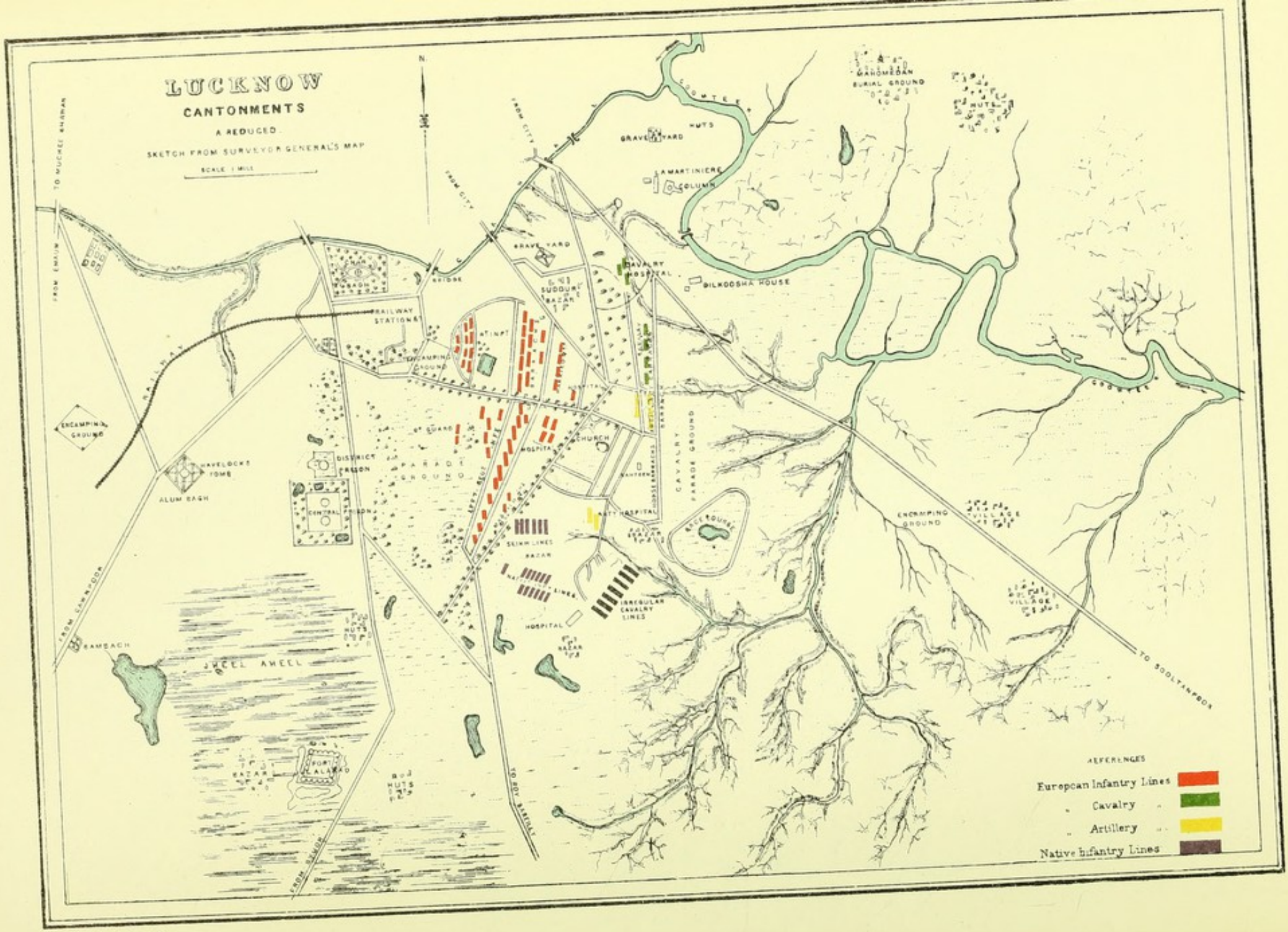
The soil at Cawnpore is very like what it is at Allahabad, but contains less kunkur.

Near the artillery barrack there was more clay than elsewhere, but, as a rule, the ground is very permeable to water.

Many of the wells are very much nearer the surface, water being found at five or ten feet, instead of fifty or sixty, as at Allahabad. Nevertheless, some of the wells examined were thirty feet below the surface. Such a variation I did not observe at Allahabad. The ground slopes towards the Ganges: I could not ascertain whether the rise or fall in the river affected the level of the water in the station; but when the river rises, it swamps a large portion of the country along its banks.

The cholera-camp of the 14th Regiment was pitched at Bhowpore. The ground about this camp was more sandy even than at Cawnpore, and more permeable to water and air. The relative degrees of permeability of this soil and of the soil near the barracks occupied by artillery, cavalry and infantry regiments are given below:—

	Soil at a depth of 4 feet from	Amount of *air* contained in 100 parts by measure of soil.	Permanganate solution required to give a permanent tint to a solution of 1 oz. soil, 10 ozs. water requiring 4 decems of the same solution.
CAWNPORE.	Cholera Camp, Bhowpore	53·3	6 decems
	„ „ Residency	46·6	4 „
	Lines occupied by 19th Hussars	46·6	4 „
	„ „ „ Royal Artillery	46·6	4 „
	„ „ „ 14th Regiment	50·0	4 „



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Concerning the amount of organic matter in the soil, the same remarks will apply to this as were made relative to the soil at Allahabad. The soil from the camp at Bhowpore contained more than any of the others.

LUCKNOW.

The European troops at this station suffered very severely from cholera, nearly a hundred deaths having taken place during the month of August, the men who had newly arrived from England, or had only lately been brought down from the hills, contributing most largely to swell this number.

Whilst visiting the various parts of this city, one could but note the extent to which it is intersected by ravines or *nullahs*, a faint conception of which may be obtained by observing the shaded portion of the accompanying little map, as well as of the swampy nature of the surrounding country. Some of these ravines are very deep, and contained filth, others contained water which flowed into the Goomtee.

Much valuable information was obtained from Dr. Sutherland, the Sanitary Commissioner for Oude, concerning the course of the epidemic, which he had carefully noted on the spot; nevertheless, no clue could be obtained as to the origin of the cause of this mortality, or the mode by which it spread. In some cases the disease seemed to be localized to a particular spot, but in others no indication of such localization could be traced. As an example of the former, the following will aptly serve :—

A man was seized with cholera in a barrack on the ground floor, and rapidly succumbed. The bed and bedding was removed and another replaced, which was occupied that night by another man, who was apparently perfectly well; he also sickened and died the same night! Another: a case occurred in the jail of a man who for a long time previously was not known to have been in communication with a single person from outside. His food and drink were precisely similar to the food and drink of the other prisoners. He was suddenly seized with cholera, and death resulted in a very short time, but the disease did not spread in the jail.

What was the nature of the ground above which these persons lived? No difference could be detected between these and other places in this respect. The upper two or three feet consisted of rubbish, which had been used for "filling up;" then came a layer of sandy soil from two to three feet deep, which was quite moist, below which was a thin stratum of yellowish clay not sufficently impermeable so as to be capable of holding water for any length of time, the permanent water-level being about thirty feet from the surface. This is attained by digging through some twenty feet of a white sandy soil. Speaking in general terms, this description will apply to the whole of the soil upon which Lucknow stands. It contains considerably more clay than exists in the stations already described, and was subsequently ascertained to be of a rather more impermeable nature.

It contained, however, in most places more organic matter, and the specific gravity of its solution was higher.

	Soil obtained from	pth.	Amount of *air* contained in 100 parts by measure.	Permanganate solution required to give a permanent tint to a solution of 1oz soil, 10 ozs. water requiring 4 decems of the same solution.
		Feet.		
LUCKNOW.	No. 4 Barrack, occupied by Royal Artillery ...	3	50·	6 decems
	„ 2 „ „ „ „ , ...	3	53·3	10 „
	„ 2 „ „ „ „ „ ...	6	53·3	10 „
	Hospital „ „ „ „ ...	3	53·3	8 „
	„ „ „ „ „ ...	6	53·3	...
	No. 12 Barrack, occupied by 62nd	3	53·3	16 „
	„ 12 „ „ „ „	6	50·	...
	„ 2 „ „ „ „	3	50·	12 „
	„ 2 „ „ by 102nd	3	53·3	12 „
	„ 4 „ „ „ „	3	50·	5 „
	„ 6 „ „ „ „	3	50·	14 „
	„ 3, Married Quarters, 5th Lancers	3	50·	...
	„ 2 „ „ „ „	3	46·6	6 „
	Jail, No. 7 building	3	50·	5 „
	„ „ „	6	50·	...

Several specimens of soil were examined microscopically, but nothing could be detected in the moistened soil for the first two or three days, presenting unmistakable evidence of vitality. Infusorial animalcules of many kinds gradually appeared, but I could not state that any marked differences existed in the various specimens observed. A figure of those which revived in some soil, from No. 2 married quarters of the 5th Lancers, will serve to illustrate what these were (Fig. xcii).

In one sample, however, some very interesting low forms of life appeared, about which Mr. Huxley and Häckel have lately written so much. The test tube in which this particular sample (from a depth of six feet in No. 2 barrack occupied by Royal Artillery) was seen was fortunately a very thin one, and permitted the use of a high power when placed on the stage of the microscope. The bodies observed consisted of minute masses of translucent, colourless jelly, without nucleus or contractile vesicle; in short, not the slightest evidence of

structure existed. Their movements were very slow, slower than ordinary amœbæ, and being translucent, it was only by careful illumination that they could be watched. Two of them are sketched at Fig. xciii, in the act of protruding long processes of their substance among some animalculæ which have become encysted on the walls of the tube. This moving substance presents precisely the same microscopical appearances as the hyaline, glary matter surrounding the encysted bodies. The little colony depicted of the latter was watched for several weeks, but no changes took place, consequently the nature of the encysted bodies could not be made out. It is very remarkable that such bodies retain their vitality so long, as they must have been imbedded in this dry soil for several years.

FYZABAD.

There were a few cases of cholera in this station also, but fortunately only two deaths occurred among the European soldiers. The cantonment is situated on slightly elevated ground on the banks of the Gogra, but no part of it is swamped by this river, nor is it believed that the rise and fall of the river affects the condition of the wells.

The soil is sandy everywhere, except near the bed of the river, where there are more traces of clay. Here and there a layer of kunkur is interposed between the upper more clayey layer and the lower one.

A few samples of the soil were preserved for subsequent examination, the result of which may be seen in the table below.

On being microscopically examined, nothing which could possibly be construed as having the most remote connection with cholera could be seen. No spores of fungi could be identified, and the infusoria which became revived in the course of a few days were of the ordinary kind (Fig. xciv).

	Soil at a depth of 4 feet from	Amount of *air* contained in 100 parts by measure.	Permanganate solution required to give a permanent tint to 1 oz. soil, 10 ozs. water requiring 4 decems of the same solution.
FYZABAD.	No. 13 Barrack (11th Regiment)	50·	5 decems
	No. 17 Barrack (11th Regiment)	50·	
	Hospital (11th Regiment)	53·3	

AGRA.

This station escaped with one death from cholera among the European troops, but the native population in the jail as well as in the bazaars suffered considerably.

Dr. Christison very kindly showed me over the whole station, so that, in spite of the shortness of the visit, a fair idea was obtained of its physical geography. As at Lucknow, ravines intersect it in every direction, and for the most part contained filth. In connection with this subject, there is a popular belief amongst the more intelligent native community that, when the river Jumna flows on the city side of a sand embankment which has formed in its bed, cholera does not prevail at Agra, as the river carries all the filth away, but when it flows on the off side, the disease is more liable to make its appearance. There may or there may not be something in this; there is, however, a serious objection to the river flowing on the city side, on account of its tendency to undermine the fortress.

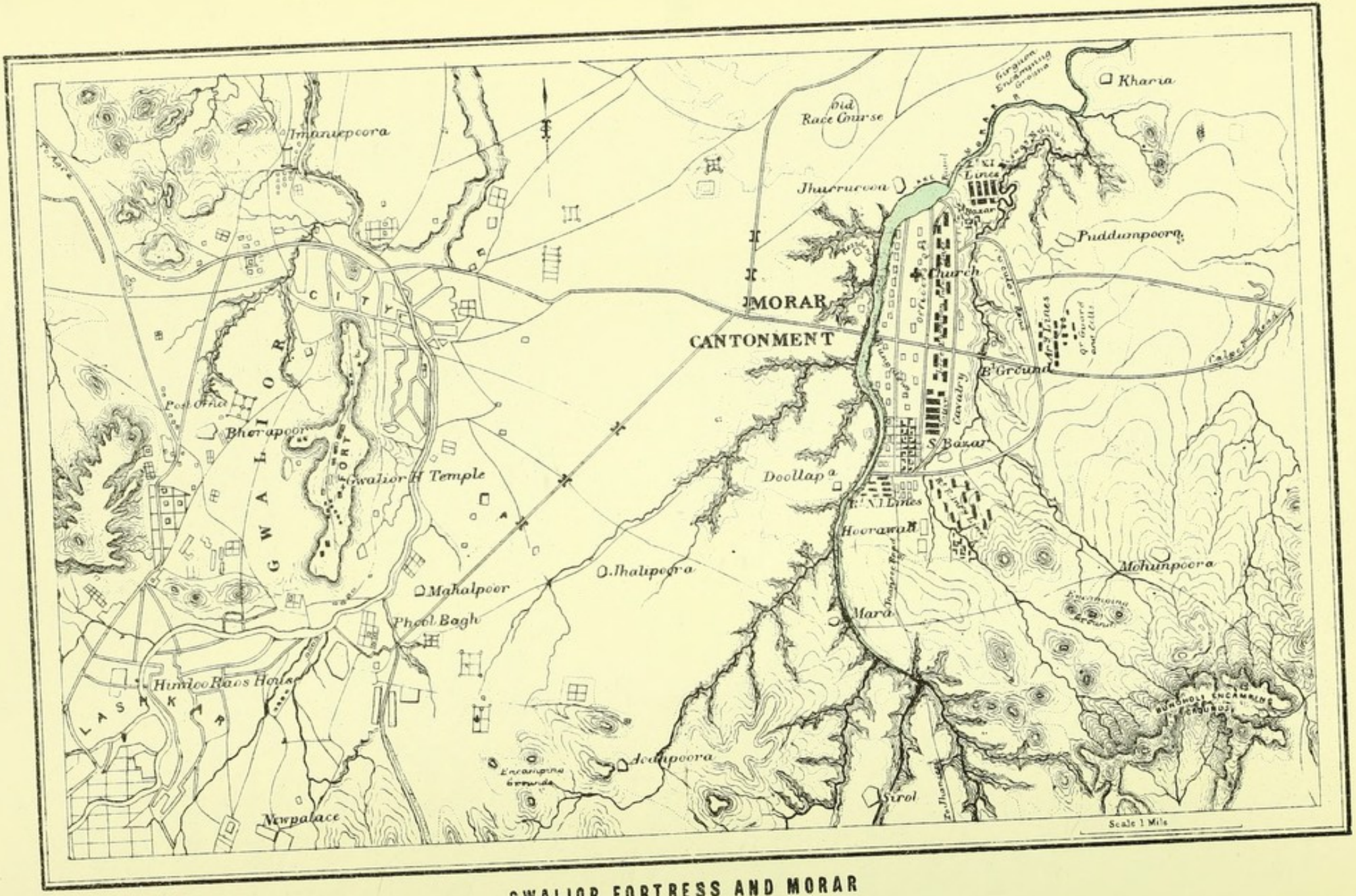
The wells are very deep, fifty to sixty feet, and the water brackish, but whether the depth of the wells is governed by the amount of water in the river, I was unable to ascertain. This information, however, will shortly be obtained in connection with the registration of the water-level established here as elsewhere.

MORAR.

When this station and the adjoining fortress of Gwalior were visited, nearly a hundred deaths from cholera had occurred among the European troops, although it was formerly considered one of the places exempted from epidemics of cholera. They had suffered severely in April, and still more so in August, sunstroke having been exceedingly prevalent among the native population as well as cholera. Every effort was made to get all the information possible concerning the epidemic, more especially relating to those points which seemed to bear upon the question as to whether or not the origin and spread of the disease had any connection with the ground upon which the people stood.

The cantonment is situate on a low-lying plain, surrounded by numerous hills on three sides, with the river Morar on the other. Some of the barracks are situated below the level of the river, so that the drains have to be taken in another direction. Other barracks, such as the ones allotted to the Artillery, are about seventeen feet above the level of the Morar.

An embankment has been erected across the bed of the river, so as to provide the station with a sheet of "ornamental water," about a quarter of a mile at its widest part, and increasing the depth of the river for about two miles above the dam. It is not improbable that Dr. Pettenkofer, had he been here, would have made



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GWALIOR FORTRESS AND MORAR

A PORTION OF SURVEYOR GENERAL'S MAP.

minute inquiries as to the extent of moisture supplied to the neighbouring subsoil by this artificial lake.

The wells are from twenty to forty feet deep; the variation is said to be about five. The water is considered to be good. Dr. Whitwell has examined it very lately, and has kindly favoured me with the particulars of the analysis of an average sample; in this there is not a large amount of organic matter, and no excess of deleterious salts. There are two kinds of soil at Morar, the *red* and *black* soil; both contain persalts of iron, with lime and magnesia, but no *nitrates* nor *nitrites*, as one would have expected to find, had the ground been tainted to any great extent by the ordure of other days; nor was the amount of oxidisable matter, as ascertained by the permanganate of potash solution, by any means excessive, indicating that the barracks and their surroundings had not recently been subjected to contamination.

The "black soil" was not universally distributed over the surface. Many yards of excavations were examined in which not a trace of this kind of soil existed; in others, again, a stratum of it was seen extending for long distances; at one end the layer might be ten feet, or more, in thickness, gradually diminishing until it was finally lost in the red; below these, a gritty, sandy layer exists, in which water is found. The foundation of several blocks of buildings, which were about being erected, were seen to present this uneven distribution of black and red soil, consequently the floorings of such buildings will vary in the extent to which they are permeable to gases, etc., from below; because the porosity of the red earth is considerably greater than that of the black. If Pettenkofer's theory be true, a building placed on this black clayey soil ought to be in a better sanitary condition than those built on the red—other things being equal. The relative porosity and amount of organic matter may be ascertained by reference to the table at the end of this paragraph. The samples enumerated are only a few of the ones examined, General Vaughan having most kindly procured specimens from every portion of the cantonment.

The cholera-camp was four or five miles out of the station, near the summit of two or three little rocky hills, the hospital apparently having a little hill for itself.

The *Fortress of Gwalior* is about six miles to the west of the cantonment of Morar. It stands on a rock whose summit is about $1\frac{3}{4}$ mile in length and about $\frac{1}{2}$ mile across in its widest part, and from 300 to 400 feet high, the ascent to which is very steep. Immense fissures may be observed in the rock whilst ascending the steep towards the gate at the entrance of the fort, these being for the most part filled with earth. On entering the fortress, nothing is seen but huge blocks of buildings standing on a barren rock strewn with a few half-withered trees, or rather shrubs. The surface of the rock is naturally very uneven, stone forming the foundation of one end of a building, whilst frequently "made" soil, to the

depth of twenty or thirty feet, forms the foundation of the other. The rock itself is a sandstone, splits to any extent, and very easily worked when wet, but excessively hard when dry. It is porous to the extent of one-third of its bulk, consequently able to retain a great amount of any sewage that may be thrown upon it.

The heat on this rock is very great; it is much complained of, especially as it continues during nearly the whole night, because by the time that it begins to cool, the rays of the sun are directed towards it again.

The samples of soil obtained consisted entirely of rubbish; there does not seem to be an inch in the place undisturbed by man until the bare rock is attained.

Table showing relative porosity and organic matter in the soil.

	Soil from	Depth.	Amount of *air* in 100 parts of soil by measure.	Permanganate solution required to give a permanent tint to 1 oz. soil, 10 ozs. water requiring 4 decems of same solution.
MORAR.	(*Red.*)			
	No. 4 Barrack, occupied by R.A.	3	46·6	6 decems
	„ „ „ „ „ „	6	46·6	9 „
	„ 9 „ „ „ 103rd	3	66·	6 „
	„ 2 „ „ „ „	3	...	5 „
	„ 4 „ „ „ R.A. (yellow clay)	3	45·	4 „
	(*Black.*)			
	No. 2 Barrack, occupied by R.A.	3	34·	5 „
	„ „ „ „ „ „	6	36·	4 „
	„ 6 „ „ „ Md. Qrs. R.A. ...	...	33·	6 „

MEERUT.

Cholera visited this station in September and the beginning of October, having been preceded by a heavy fall of rain. Nineteen cases occurred, with fourteen deaths, among the European soldiers, whilst about a hundred cases occurred among the natives of the bazaar. The cantonment is situated on a large plain, with scarcely any fall, consequently not admitting of good natural drainage. There is a deep ravine separating the European and the Native lines, on either side of which for a short distance good clay is found; otherwise it is rather sandy everywhere, quicksand being frequently met with in digging the foundation of a building.

The wells are not very deep, water being generally attained at about ten to twelve

feet from the surface, the extreme variation in which is, according to Dr. Berkeley, about five feet. Rain rapidly affects the level of the water in the wells, the amount of rise of the latter being almost equal to the fall of the former. This is the reverse of what occurs at Allahabad, where a great portion of the rainfall either drains to the river or is evaporated before reaching the permanent water-level. This intimate connection between the wells and the surface at Meerut is of great sanitary importance. Seeing the ease with which any sewage may get into the wells, and as the condition of the ground does not permit of free natural drainage, it is self-evident that the greatest attention should be paid to remedying this defect by artificial means.

In the more minute examination of this soil, subsequently undertaken, no evidence existed of the ground in the vicinity of the barracks being in a polluted condition, and on the whole was rather less porous than the soils already alluded to, with the exception of the black soil at Morar.

	Soil at a depth of 4 feet from	Amount of *air* contained in 100 parts by measure	Permanganate solution required to give a permanent tint to a solution of 1 oz. soil, 10 ozs. water requiring 4 decems of same solution.
MEERUT.	Between Nos. 44 and 46 (105th Regiment) ...	45·	5 decems
	„ „ 34 and 39 „ „ ...	50·	6 „
	„ „ 43 and 48 „ „ ...	50·	5 „
	„ „ 1 and 2 (4th Hussars)	55·	5 „
	„ „ 13 and 14 „	46·3	5 „
	Married Quarters, No. 15, R.A.	50·	6 „

This soil was examined microscopically in the same manner as the others were, with somewhat similar results. During the first few days its solution contained no infusoria, at least not in motion, but subsequently they made their appearance in great numbers. These in one sample, namely, in the soil from between Nos. 1 and 2 blocks, occupied by the 4th Hussars, consisted almost entirely of various phases in the existence of *monas lens* (Figs. xcv and xcvi). These alter their form very rapidly, frequently protruding an amœba-like vesicle, as seen at Nos. 1 to 5, Fig. xcv, which represents one animalcule assuming different forms. There are also great numbers of very minute amœbæ (6) which seem to be an earlier stage of this animalcule, and when it gets older it becomes elongated (7, 8), sometimes acquiring two filaments. They are frequently seen to multiply by division, as seen in Fig. xcvi, where No. 3 runs through the stages delineated at 4 to 7 in the course of five minutes, the two at 7 becoming as perfect in all points as the original one. The green bodies in the figures, which rolled about the field, are *algæ*.

PESHAWUR.

The Sanitary Commissioner having subsequently visited Peshawur (where over 350 cases of cholera were reported as having occurred during the month of September among the European troops alone), favoured me with two samples of soil, one sample from a depth of three feet, and the other from a depth of six.

It was in hard lumps, of low specific gravity, owing to its spongy nature, exceedingly like a piece of pumice stone, and when applied to the lips, so freely could air be made to pass through, that a feather placed on one end of a table could be readily blown to the other.

Its solution was slightly alkaline, and contained rather more organic matter than the average, as may be seen from the subjoined table.

	Soil from a depth of	Amount of *air* in 100 parts by measure.	Permanganate solution required to give a permanent tint to a solution of 1 oz. soil, 10 ozs. water requiring 4 decems of same solution.
	Feet		
PESHAWUR.	3	50·	10 decems
	6	50·	8 ,,

It was subjected to a prolonged microscopic examination. During the first three days a number of molecules developed in the fluid containing the three feet soil; then an abundance of animalcules like the ones alluded to in connection with the Meerut soil (Fig. xcvii, 2, 3.) At Nos. 5, 6, and 7 various forms are depicted, assumed by one in two minutes, which was also occasionally seen to jerk suddenly in the same manner as 2 and 3. The reddish body at 1 is a spore, probably belonging to the *Dematiei* family—a very common fungus.

The test tube containing the other sample of soil from a depth of six feet having been left undisturbed for a week, was, on examination, found to contain several examples of slimy bodies of a lower organization than the amœba, there being no contractile vesicle, although generally one or more vacuoles were seen (c). Nearly all of them contain molecular matter, which flows towards the portion of substance in the act of being projected. Figures cii to cvii illustrate the various forms assumed by one of these in the course of twenty minutes. They were not seen to divide, nor did the protruded processes become amalgamated when they crossed each other. A great number of vibriones developed in this solution, more so than I had observed in any of the other specimens of soil examined, and were very active. These are figured at ci, amongst which one of the just described *moners* is seen with extended

processes, which were observed to wander throughout the fluid something like the "horns" of a snail. To these processes monads and small vibriones adhered, which were drawn into the substance of the *moner* as the processes were retracted. Three days afterwards, all the *moners* had become spherical and perfectly still (cvii).

The other animalcules which made their appearance were those commonly met with, and require no special description. They are figured at xcvii and xcix, where the names are also given.

Having already alluded to the chief points in connection with these experiments, whilst describing the various places visited, it is not considered necessary to refer to them again. The observations concerning the physical geography of the stations are of a more superficial nature than I could have desired, but the time at my disposal was very limited, and correct information on such matters could not be obtained without personal inspection. It will, indeed, be evident that the experiments referred to in the whole of this report are of an elementary nature. This is, in part, owing to the short period which has elapsed since they were commenced, partly also to my having been tempted, by the desire for results, to keep too many irons in the fire. I trust, however, that what has been done will prove to be a foundation whereupon better things may be built.

In conclusion, I respectfully tender my most sincere thanks to Dr. Muir, C.B., Inspector General of Hospitals, British Troops, for the assistance which he has so gladly rendered on every possible occasion to further this inquiry, and for the personal interest he has taken in the details thereof; also to Dr. Cunningham, the Sanitary Commissioner with the Government of India, for similar aid, not less cheerfully given.

A CONDENSED DESCRIPTION OF THE ILLUSTRATIONS.

PLATE I.

A copy of Hallier's drawing of the cholera fungus.

	NOS
Mature cholera "*cyst*," swollen and ruptured	1
Cholera cysts less mature	2
Swelled "*spores*," which were supposed to have escaped from cholera cysts; some of them are seen degenerating into "*Micrococcus*"	3
"*Micrococcus Colonies*"—(*a*) Colony formed by the breaking up of a single spore. (*b*) Ditto still further broken up. (*c*) A group of "Colonies" corresponding to several spores. (*d*) Germinating "*Micrococcus*"	4
"*Micrococcus*" germinating	5
Ditto filaments beginning to be formed	6
Highly developed filament with cyst (*c*), and macroconidia (*m*)	7
A cholera cyst or *sporangium* not fallen off, but still attached to its fertile filament	8
Filaments illustrating the tendency to the formation of *Tilletia caries*. What was considered a matured spore of the latter is marked *sp*	9
An aggregation of "cholera cysts"	10
A "cholera cyst" germinating	11

PLATE II.

Cholera bodies of 1849.

	FIGURES.	NOS.
The cholera bodies of Drs. Budd, Brittan, and Swayne (after *Robin*)	ii.	
Brittan's "annular bodies" in cholera (copied from *Medical Gazette*)	iii	
Swayne's "cholera cells" (copied from *Lancet*)	iv.	

PLATE III.

"Cysts" in choleraic discharges.

Cysts closely resembling Brittan's cholera bodies; consisting principally of fatty matter enveloped by fibro-albuminous material	v.-vii.	
A globular cyst-like body observed in choleraic dejecta	v.	1
Effect of liq. potassæ upon No. 1 (fatty)	,,	2-4
Two sizes of the globular cyst-like bodies as at v. 1	vi.	1-2
Appearance after the addition of acetic acid (fatty)	,,	3-5
Globular cyst-like body surrounded by a compact fibro-albuminous layer	vii.	1-2
Effect of ether after the previous application of liq. potassæ (fatty)		3-4
Bodies resembling the "cholera cells" of Swayne. They are *ova* of ordinary Round-worms	viii.-xi.	
Ova, as commonly met with in alvine discharges	viii.	1-4
Ova, the contents having assumed a somewhat defined arrangement	,,	5-6
Embryo completed	viii.	7
Embryo escaped	,,	8
Same as viii., the form having been altered by pressure.	ix.	
Effect of adding ether	,,	1
Aspect assumed after the addition of liq. potassæ subsequent to the application of ether	,,	2-5
Same as viii.—Also treated with ether. No. 3 was ruptured by pressure (ova)	x.	1-5

PLATE IV.

Organisms obtained in cholera stool.

More highly magnified specimen of Fig. viii.	xi.	
After the addition of sulphuric acid (ova)	,,	1-2
——————— of iodine and absolute alcohol (ova)	,,	3
——————— of absolute alcohol only (ova)	,,	4
Ova of *acarus* (*domesticus?*) —sometimes found in choleraic and other dejections	xii.	
Partly disintegrated *acarus* obtained in a cholera stool (magnified by a low power)	xiii.	
Highly stained specimen of the *ovum* of *Tricocephalus* (*dispar?*)—probably the body delineated at No. 2, fig. iii, in Dr. Brittan's drawing	xiv.	1
Ditto ruptured by pressure	,,	2
Highly stained specimen of the *ovum* of an *ascaris* found in the same stool (cholera) as the foregoing,—ruptured by pressure	,,	3
Mycelium escaping from an aggregation of molecules (micrococcus). Spores not visible (cholera stool)	xv.	
Germinating spores, together with mycelial filaments (cholera stool)	xvi.	

PLATE V.

Development in a cholera stool: "Isolating Apparatus."

Fungus developed in a cholera stool. A later condition observed in the preparation delineated at fig. xv, Plate IV.	xvii.	
Spores, some of which have germinated	,,	1-2
Mycelium, upon which dilatations or macroconidia (*m*) are seen	,,	3
Filaments with bulbous terminations	,,	4
Fertile filament terminated by a cyst or *sporangium*, the contents of which is seen to have contracted within the capsule	,,	5
The "Isolating Apparatus" used in some of the experiments	xviii.	
Funnel containing a plug of cotton wool	,,	1
Flask containing strong sulphuric acid	,,	2

	FIGURES.	NOS.
Shallow dish (containing a solution of permanganate of potash), with an inverted bell-glass, inside of which is a small wire stage for elevating the preparation above the level of the fluid in the dish	xviii.	3
An *Aspirator* filled with water. One arrow represents the escape of the latter, and the other arrow shows the course which the entering air has to take before it can replace the escaped water	„	4

PLATE VI.

Fungi developed in a cholera stool.

Fertile filament of *Aspergillus;* some of the spores (conidia) are seen falling off	xix.	1
——————— *Penicillium*	„	2
Cells of various sizes in the cultivation, probably modified spores	„	3
Very thin filaments terminating in excessively delicate mucor-like cysts or *sporangia*, some of which are filled with elongated spores	„	4

PLATE VII.

Mycelium developments in choleraic discharge.

Highly developed specimens of mycelial filaments, with numerous dilatations (*Macroconidia*), which separating are found as free circular cells in the field, capable of germinating like ordinary spores (cultivated in cholera discharge)	xx.	

PLATE VIII.

Fungi developed in ordinary fæcal evacuation.

Spores in process of germination	xxi.	1-2
Micrococcus	„	3
Penicillium glaucum	xxii.	1
Aspergillus	„	2
Numerous filaments of *Oidium lactis*, corresponding to the "cholera-fungus" of Thomé	xxiii.	

PLATE IX.

Fungi developed in ordinary fæcal evacuation, simulating Hallier's cholera fungus.

Spores, cysts, and filaments of *Mucor* in various stages of development	xxiv.	
Escaped spores	„	1
Detached cyst or sporangium	„	2
Cysts still attached to the fertile filaments	„	3
Heads of fertile filaments (Columella), with the remains of the ruptured cyst-capsules still attached	„	4
N.B.—Compare Nos. 2 and 3 with Hallier's figures (Plate I., Nos. 2 and 8).		
Ruptured *mucor* sporangia	xxv.	
A ruptured cyst with spores escaping	„	1
Ditto the spores having completely escaped	„	2
Ditto detached from its stalk	„	3
A *mucor* cyst detached from the fertile filament. The spores are seen to escape through the capsule	xxvi.	1
Aspergillus fructification simulating that of *mucor;* a glutinous film surrounding it, thus keeping the spores or *conidia* together. The fertile filament is seen to be partly ruptured	„	2
Detached *Aspergillus* heads of various sizes, the spores being held together by means of some glutinous material	xxvii.	1-2
Ditto in process of germination. *N.B.*—Compare with Hallier's drawing of the mature cholera-cyst in the same condition (Plate I. No. 11)	„	3

PLATE X.

Fungus developed in ordinary stool (mucor), like Hallier's cholera fungus.

	FIGURES.	NOS.
Appearance of the Mycelium on the second and third day	xxviii.	1-2
A fertile filament which crept out of the preparation, and which bore a distinct cyst on the seventh day. Defined spores could not be distinguished among the contents	,,	3
Growing-cell, in which is seen the position of the preparation through the thin covering-glass. Between this glass and the subjacent glass-slide the fungus (xxviii) above described was cultivated. The varying diameter of the segments of the circles enclosing the preparation permits the entrance of air	xxix.	

PLATE XI.

Globules of a fatty nature simulating cysts, etc.

Globules of a fatty nature simulating "cysts," "spores," etc.	xxx.	
Greenish-yellow globules which formed a considerable portion of the sediment of a cholera stool	xxxi.	
Spherical form of ditto; the tinged portion is seen to be contracted from the delicate pellicle which encloses it	xxxii.	1
Oval and irregular shape of ditto	,,	2-3
Appearance presented by the foregoing in the course of four hours	xxxiii.	
Vanished suddenly, a pale "ring" only remaining	,,	1
Granular appearance which occasionally preceded this condition	,,	2
Granular appearance of ring-like remains	,,	3-5
Spherical body with a dense, tinged substance (oil) centrally situated	,,	6
An aggregation of the foregoing globules surrounding a phosphatic crystal	xxxiv.	

PLATE XII.

Blood cells in cholera stool: Blood cells and embryo of round-worm in "chylous" urine.

Microscopic appearance of a distended blood-cell at various distances from the object-glass	xxxv.	1-5
Aspect presented by the blood-cell at the end of three hours	,,	6
Blood-cells from a cholera stool	xxxvi.	
Presenting a single hyaline protrusion, capable of being retracted	,,	1
Presenting two retractile protrusions	,,	2
The protruded portion after a time is frequently not retracted, but is seen to trail with the cell when the covering-glass is shifted, as long as the cell is visible	,,	3
Blood-cells similar to the foregoing (xxxvi) observed in "Chylous" urine	xxxvii.	
Some of the aspects presented by these cells	,,	1-5
Various forms assumed by one of the larger corpuscles present	,,	6
Embryo of a round-worm imbedded in a mass of gelatinised substance which formed in "Chylous" urine	xxxviii.	
Embryo (of a larger size than that delineated at xxxviii), after the addition of acetic acid. The hook-like appearance is only evident in certain positions	xxxix.	1
The *caudal-bursa* which became evident after prolonged action of the acid	,,	2

PLATE XIII.

Flocculi, animalculæ and forms assumed by corpuscles in cholera stool.

Hyaline appearance occasionally seen, when examined early, of the cells associated with the *flocculi* in rice-water stools	xl.	
The granular aspect presented by the preparation delineated at xl after 24 hours	xli.	
Animalculæ which appeared in the evacuation on the fifth day. These generally present a distinct nucleus and frequently two anterior filaments, which the animalculæ figured in plates xv and xvi do not	xlii.	
The *flocculi* and the cells imbedded therein observed to be granular, although examined almost immediately. The granular mass observed at the upper corner of the figure may be defined as a Micrococcus Colony, produced by the disintegration of the substance into molecules	xliii.	

	FIGURES.	NO.
Movements exhibited by the corpuscles associated with the flocculi when freed from the meshes of the membranaceous substance	xliv.	
Appearance of the *corpuscles* associated with the *flocculi* after the addition of weak acetic acid and iodine	xlv.	

PLATE XIV.

Various objects seen in a cholera stool.

The elongated form very commonly observed of the corpuscles imbedded in the flocculi. Some are granular, others are hyaline	xlvi.	
Appearance presented by the preparation (xlvi) after the addition of iodine solution	xlvii.	
Sarcinæ, as commonly observed in cholera and other stools	xlviii.	
Accumulations of a fatty nature	xlix.	1
Little pellets which possess the power of altering in form and position	,,	2
Forms assumed by *one* of the foregoing	,,	
Very active animalculæ	,,	4
Various forms assumed by the gelatinous-looking substance depicted at xlix, No. 3.	l.	
Animalculæ in a globular still condition	li.	1
Various forms assumed by *one* of the foregoing	,,	2–5

PLATE XV.

Various stages in the existence of the animalculæ which have been observed in alvine dejections.

The aspects usually presented by these animalculæ when seen in evacuations	lii.	
Appearance of the preparation, delineated at figures xlix–lii on the fourth day: many of these jelly-like masses are animalculæ which have become inactive	liii.	
Various forms assumed by a single animalcule immediately before it became inactive, as at liii	liv.	
Effect of re-agents on the masses depicted at liii	lv.	
After the addition of acetic acid	,,	1–2
——————— absolute alcohol	,,	4
——————— ether and alcohol	,,	3
Mr. Berkeley's growing-cell	lvi.	
Three stages in the "life history" of the animalculæ, above described, which were followed out by continuous observation in the Berkeley-cell	lvii.	

PLATE XVI.

Cholera stool: Healthy blood added to cholera stool: Stool of healthy person.

Large granular cells, amongst which very active animalculæ are seen (cholera evacuation)	lviii.	
Cells associated with the foregoing (lviii) and closely resembling them, but exhibiting pseudopodial movements	lix.	
With a single vesicle-like protrusion	,,	1
Exhibiting protrusions from more than one portion of its substance	,,	2
The projected pseudopod appears to have passed through an external envelope in one case (3), whilst the projection seems to consist of the external layer itself in the other (4)	,,	3–4
Projections which were no longer retractile	,,	5
A large corpuscle presenting movements of an amœboid character	,,	6
Blood-cells altered in appearance; the result of osmosis	,,	7
Animalcule (cholera stool)	,,	8
Blood-cells	lx.	1
One of the blood-cells from the group (No. 1) altered in appearance by one of the animalcules	,,	2–4
Animalculæ with blood-cells intimately adherent to their substance. The animalculæ in this case are somewhat larger than ordinarily met with (cholera stool)	,,	5
Appearance assumed by blood corpuscles from a *healthy* person, which had been added to a portion of filtered cholera stool	lxi.	

	FIGURES.	NOS.
Stellate appearance of the red cells	lxi.	1
White corpuscles	,,	2
White corpuscles spread out like an amœba	,,	3
Subsequent aspect of the red cells. The condition usually observed when found in alvine discharges	,,	4
The alterations observed to take place in a single white corpuscle	,,	5
White corpuscle surrounded by a halo-like pellicle	,,	6
Corpuscles and animalculæ observed in the stool of a perfectly *healthy person*	lxii.	
As seen immediately after being voided	,,	
As they appeared 24 hours later	lxiii.	

PLATE XVII.

Development of the lowest forms of life in organic solutions.

Monads	lxiv.	1
Bacteria	,,	2
Vibriones	,,	3
Leptothrix	,,	4
Appearances presented in a filtered solution of organic matter (*unboiled*) on the second day	lxv.	
Ditto third day, showing the appearance of the "heaps"	lxvi.	
Appearances presented in a filtered solution of organic matter (*unboiled*) on the fifth day, vibriones increased in length	lxvii.	
Ditto, ditto, circular bodies developed in the midst of the heaps	lxviii.	
Developed on the third day in a solution of organic matter (*boiled*)	lxix.	

PLATE XVIII.

Development in organic solutions of the lower forms of life.

Objects presented in a *boiled* and filtered solution of organic matter towards the end of the third week	lxx.	
The animalculæ present in the above solution, which towards the end of the fifth week could not be distinguished from those described as being present in the alvine discharges, both in the active and "still" condition. The nature of the green cells in the midst of the molecules is not known	lxxi.	
Spores developed in another test tube containing a portion of the organic solution used at lxix–lxxi. *N.B.*—This tube had been breathed into	lxxii.	
Ditto in process of germination	lxxiii.	
The appearance of the spores (lxxii) as modified by the addition of gum water	lxxiv.	
Dr. Maddox's slide for cultivation experiments. Two strips of tinfoil are seen to intervene between the glass-slide and the thin covering-glass, with the preparation in the centre. The arrows indicate the spaces left open for the admission of air	lxxv.	

PLATE XIX.

Development in solutions of organic matter of low forms of life.

Amœboid bodies which appeared in a boiled and filtered solution of organic matter on the fourth day	lxxvi.	
The various forms assumed by one amœba	,,	1
A portion of the substance of the amœba becomes detached	,,	2
The detached portion exhibits movements	,,	3
Process of division into two portions of nearly equal size	,,	4
Segmentation complete	,,	5
Appearance of a contractile vacuole in the detached segment	,,	6
Ditto fifth day	lxxvii.	
Amœbæ	,,	1
Ditto becoming stellate on the addition of water	,,	2
The form subsequently assumed by No. 2	,,	3

	FIGURES.	NOS.
The subsequent history of the amœbæ (lxxvi–vii)	lxxviii.	
Amœbæ creeping across the field and discharging their contents	„	1
Amœbæ, which became circular, and active movement was set up among the aggregated molecules. A bright halo is seen to surround the globular mass	„	2
The halo disappears and the contractile vesicle vanishes	„	3
The mass becomes broken up altogether	„	4
Illustrating the changes which occurred in two solutions of organic matter obtained from the same source, placed on under two covering-glasses upon *one* slide	lxxix–lxxxiii.	
Circular "yeast" cells and *anguillulæ?* which appeared in one of the preparations	lxxix.	
Developmental stages of a young *paramecium*	lxxx.	
Corpuscles developed in the midst of a heap of minute molecules	„	1
Growth of the corpuscles	„	2
A contractile vacuole becomes evident	„	3
The animalcule after its escape from the corpuscle (3)	„	4
Irregular outline assumed by the animalcule in a thick fluid	„	5–6
The animalculæ become encysted, and in this condition multiply by segmentation; some are seen to exhibit contractile vacuoles, others not	lxxxi.	

Plate XX.

Developments in organic solutions.

A young *paramecium* getting out of the encysted condition	lxxxii.	
Two encysted *paramecia;* active movements were set up amongst molecules of the smaller one, and the cyst became detached from its fellow	„	1
The molecular contents is seen to have assumed the form of an animalcule, which by its active movements caused the capsule to become attenuated	„	2
The escaped animalcule	„	3
The remains of the cyst	„	4
A ruptured cyst—animalcule not escaped	lxxxiii.	1
Animalcule escaping, but is still enveloped by a delicate capsule (*schleier*)	„	2
Empty cysts	„	3–4
Segmentation into four animalcules has occurred in the cyst	„	5
After several encysting processes, a *ciliated* infusorium appeared on the slide	„	6
Forms of life which developed in a cholera stool	lxxxiv–ix.	
The animalcule described as occurring in alvine discharges in the active and in the "still" condition	lxxxiv.	
Effect of the addition of carmine solution upon the above preparation, everything in the field being tinted pretty much to the same extent	lxxxv.	
"Yeast" cells which appeared in the midst of the foregoing on the third day	lxxxvi.	
Fertile filaments bearing *Sporangia* with spores; the latter were readily distinguishable about the fourteenth day	lxxxvii.	

Plate XXI.

Fungi developed in cholera discharge.

Earlier condition of lxxxvii: the filaments are intersected by those of Penicillium	lxxxviii.	
Penicillium viride	„	1
Penicillium glaucum	„	2
A more fully developed specimen of lxxxvii. Some of the filaments are seen to present dilatations or *macroconidia*	lxxxix.	

Plate XXII.

Objects observed in moistened soil from Allahabad on third and succeeding days.

Various stages of *Monas lens* principally; observed in soil at a depth of four feet from the immediate vicinity of the newly-erected barracks	xc.	1-8
Minute Zoospores, together with animalculæ in the "still" and active condition, precisely similar to those described as being present in alvine discharges. Developed in moistened soil obtained from the flooring of the Clydesdale Barracks at a depth of four feet	xci.	

	FIGURES.	NOS.
Developed in moistened soil from Lucknow	xcii-iii.	
Panophrys in two positions	,,	
Euglenæ or *Astasiæ*	,,	
Amphileptus	,,	
Two *Monera* are shown in the act of creeping across the field. One is seen to curve its Pseudopoda around the circular cells present—the encysted condition of some animalculæ. A ciliated infusorium may also be observed in the figure	xciii.	
Developed in moistened soil from Fyzabad	xciv.	
Zoosporoids	,	1-2
Monas lens	,,	3
Paramecium (?)	,,	4
Coleps hirtus	,,	5
Developed in moistened soil from Meerut	xcv-xcvi.	
Algæ	xcv.	1-2
Monas lens undergoing segmentation	,,	3-7

Plate XXIII.

Objects observed in some moistened soil.

Various stages of *Monas lens* from Meerut	xcvi.	1-6
Euglenæ (?)	,	7-8
Developed in moistened soil from Peshawur	xcvii-cvii.	
Spore of *Helminthosporium?*	xcvii.	1
Monas lens	,,	2-3
Various forms assumed by *one* amœba	,,	4
Panophrys in various positions	xcviii.	1-5
Amphileptus	,,	6
A Paramecium dividing	xcix.	1-4
One of the segments after complete division: the arrow indicates the direction of the current	,,	5
Minute *Monera* presenting no nucleus nor contractile vesicle	c.	
A *Moner* throwing out Pseudopoda in all directions. A great number of vibriones are seen in the field	ci.	

Plate XXIV.

Amœboid-like forms developed in moistened soil from Peshawur.

Various forms assumed by a single *Moner* in the course of two minutes. The vacuolæ are not permanent, nor do they appear rhythmically. The coloured granules are drawn into its substance during the retraction of the pseudopods. The engulphed granules flow in the direction of the projected part, as indicated by the arrow at cii and cv	cii-vi.	
Two *Monera* which have become spherical and still (under a lower magnifying power)	cvii.	

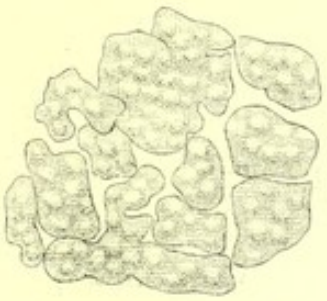
Maps.

Allahabad, opposite page	45
Lucknow, opposite page	49
Morar and Gwalior, opposite page	53

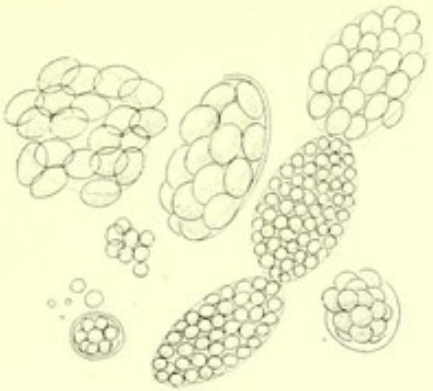
*** The illustrations are all drawn to scale with the aid of the *camera lucida*, and the magnifying power used is attached to each figure.

The diameter of the object in any of the figures may readily be obtained by comparing them with the one-thousandth of an inch scale placed at the foot of each plate.

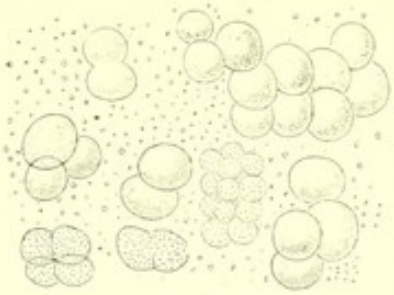
These plates have been engraved in the Office of the Surveyor-General of India. They are very faithful copies of the original drawings, and will bear favourable comparison with the work of engravers in Europe, who are habitually engaged in this kind of employment. I am under great obligation to the Surveyor-General and also to the Assistant Surveyor-General, Captain W. G. Murray, under whose immediate superintendence the work has been done.



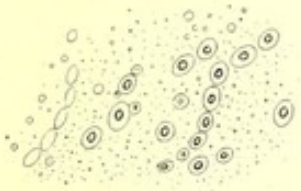
1. Mature "Cysts" ruptured



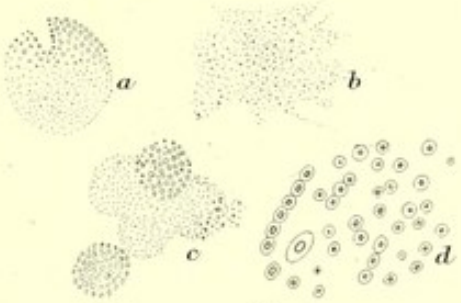
2. "Cysts" less mature



3. Swelled "Spores"
some degenerating into Micrococcus

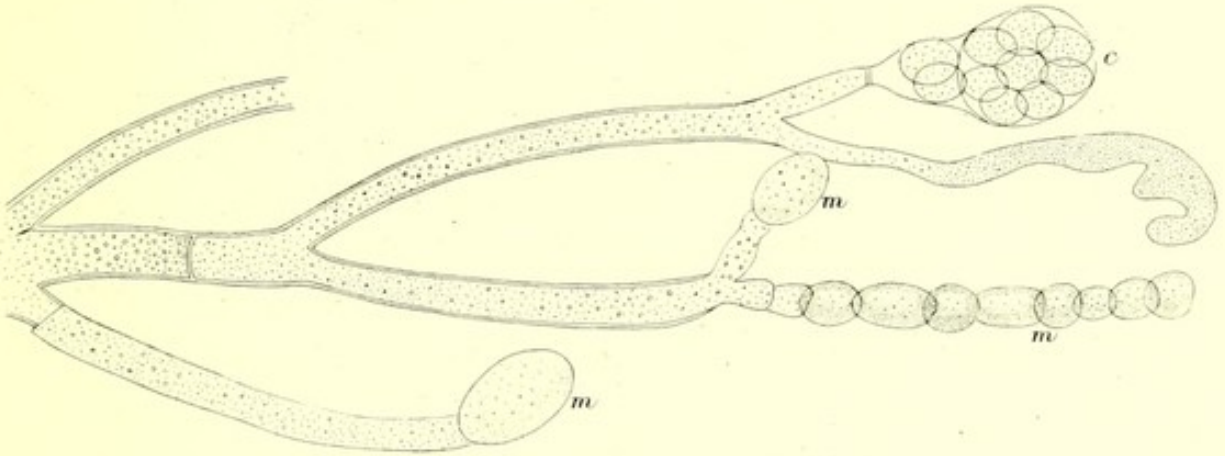


5. Micrococcus germinating

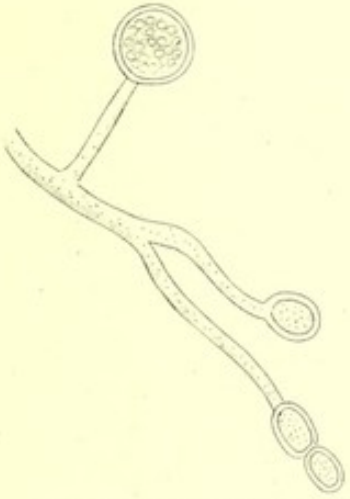


4. Micrococcus Colonies *a–c*
d Ditto germinating

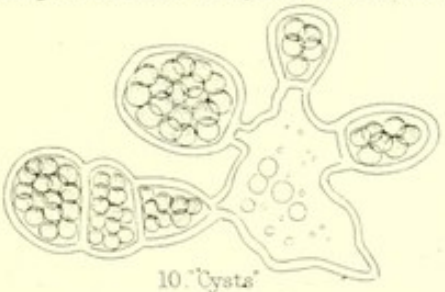
6. Filaments
beginning to be formed



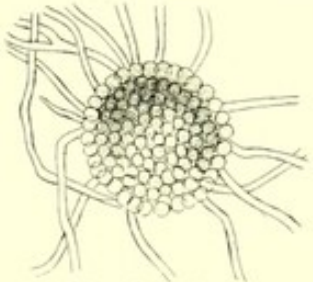
7. Highly developed Filament, with Cyst (*c*) and Macroconidia (*m*)



8. A young Cyst not fallen off



10. "Cysts"



11. "Cysts" germinating

9. Filaments showing tendency
to formation of Tilletia Caries

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FIG. I. HALLIERS DRAWING OF THE "CHOLERA FUNGUS"

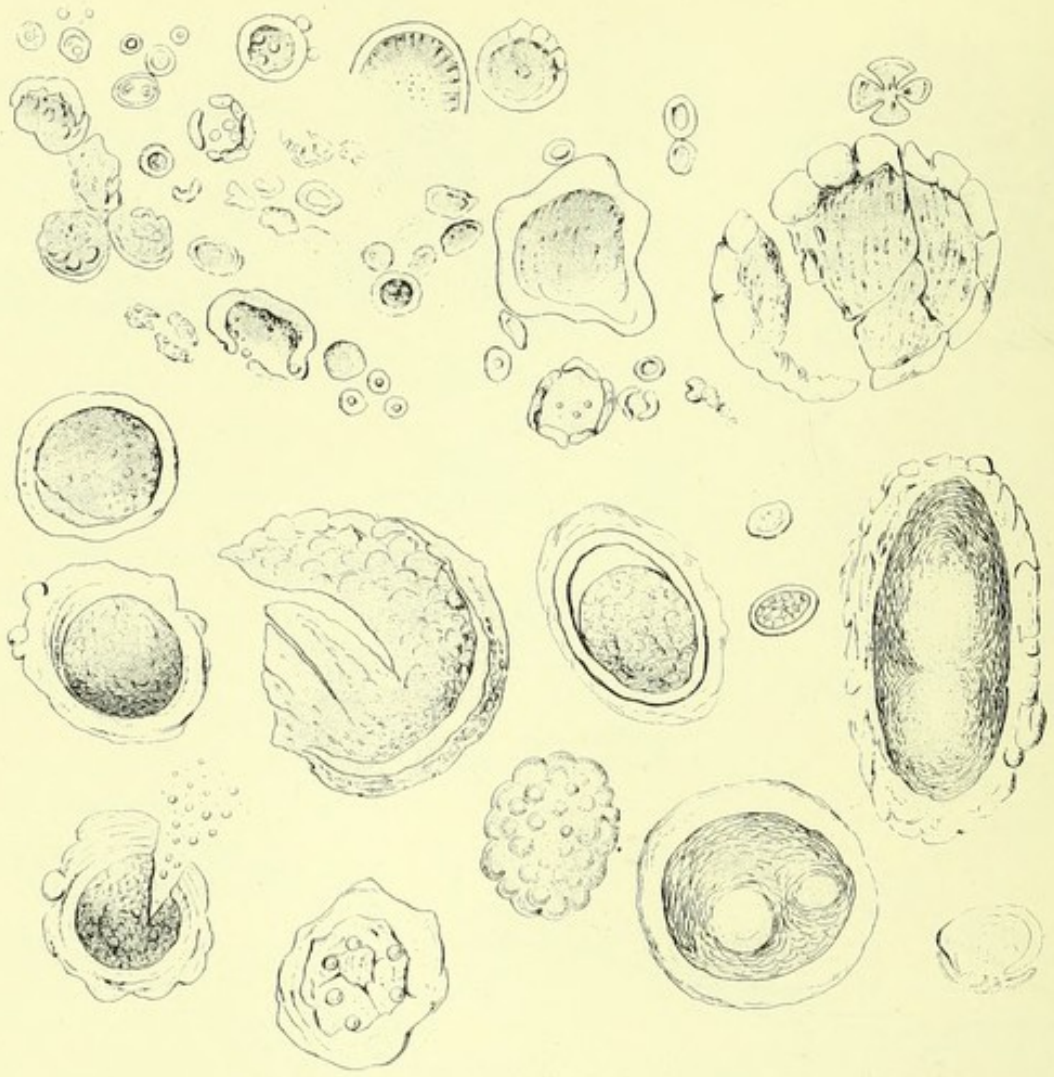

FIG. II. CHOLERA BODIES of Drs BUDD. BRITTAN. & SWAYNE (after ROBIN)

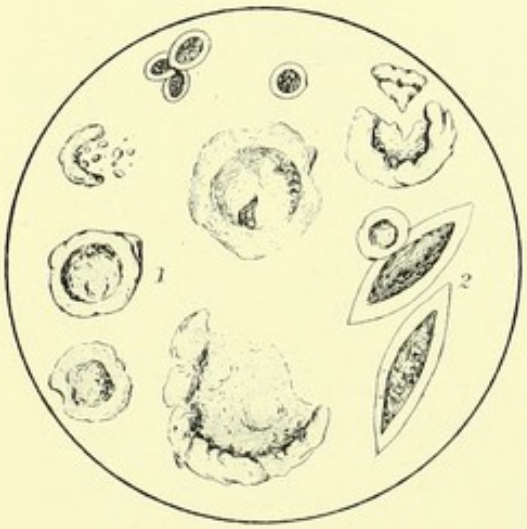

FIG. III. Dr BRITTAN'S "ANNULAR BODIES"
Copied from "Medical Gazette"

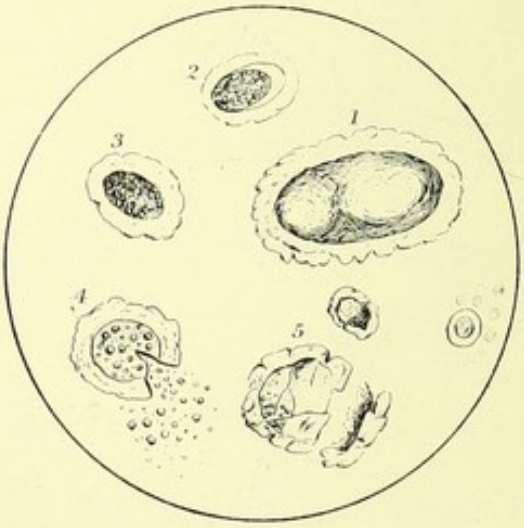

FIG IV. Dr SWAYNE'S "CHOLERA CELLS"
Copied from "Lancet"

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FIGS. II – IV. CHOLERA BODIES OF 1849.

FIG V. × 250
2.to 4. Effect of Liq. Potassæ upon N° *1.* (Fatty)

FIG. VI. × 250
3.-5. Action of Acetic acid upon N° *1.-2.* (Fatty)

FIG. VII. × 250
1.-2. Required the addition of Liq Potassæ to dissolve the "Capsules" before Ether acted upon them *3.-4.* (Fatty)

FIG. VIII. × 250
1. to 4. As commonly found *5.-6.* A more definite form assumed by Contents *7.* Embryo completed *8.* Escaped embryo (Ova)

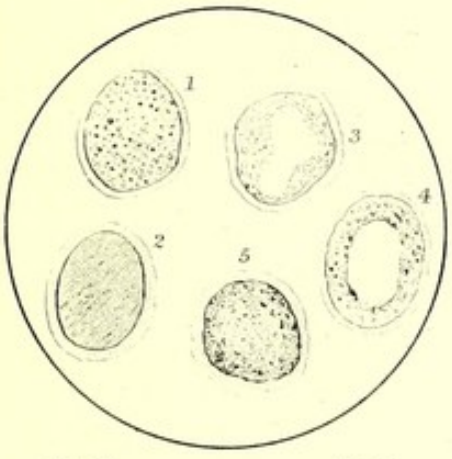

FIG. IX. × 250
Same as VIII.
1. Effect of Ether. *2, to 5.* Effect of the addition of Liq. Potassæ (Ova)

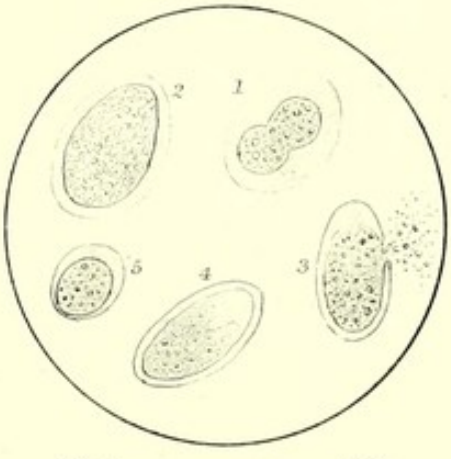

FIG. X. × 250
Same as VIII.
1. to 5. Action of Ether. *3.* Ruptured by pressure (Ova.)

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FIGS. V.–X. "CYSTS" IN CHOLERAIC DISCHARGES.

1000th of an inch —— × 250

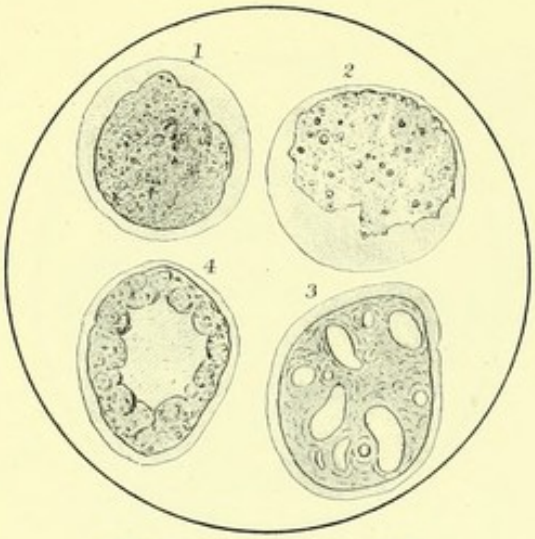

FIG. XI. × 500
1.2. After Sulphuric acid *3.* Iodine & Alcohol
4. Alcohol only (OVA)

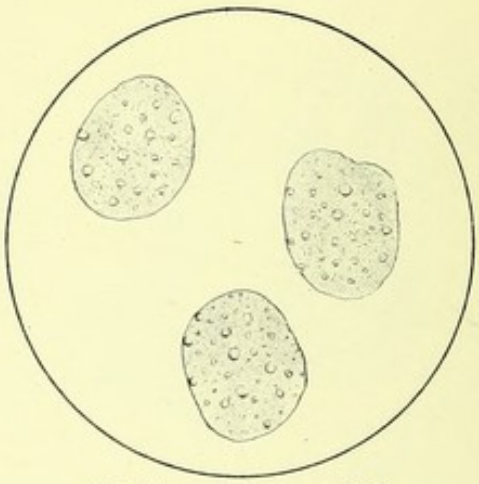

FIG. XII. ×320
Ova of Acarus (domesticus?)

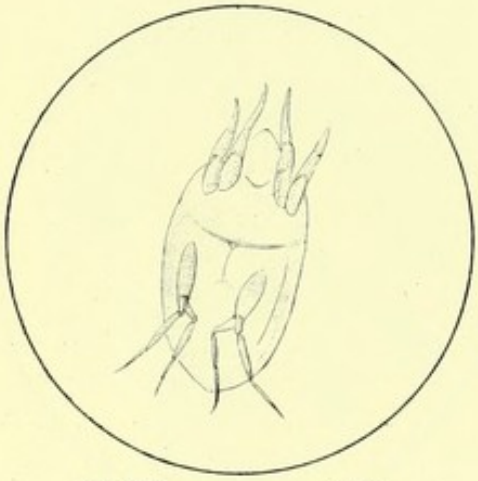

FIG. XIII. × 150
Partly disintegrated Acarus found in a cholera stool

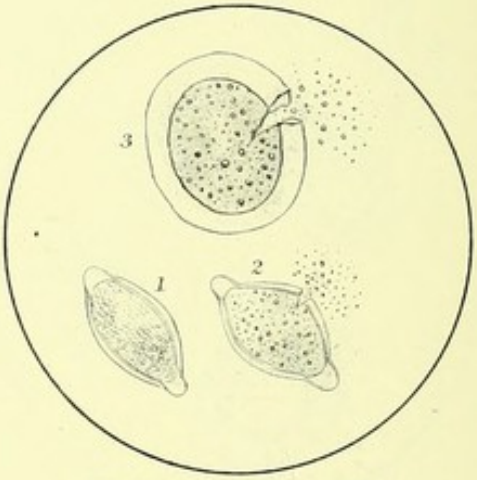

FIG. XIV. × 300
1. Ovum of Tricocephalus (dispar?)
2. ____ ruptured
3. ____ Ascaris (Mystax?) ruptured

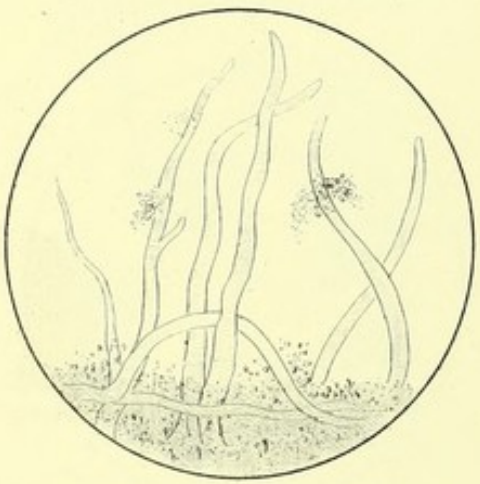

FIG. XV. ×300
Mycelium escaping from a mass of Micrococcus

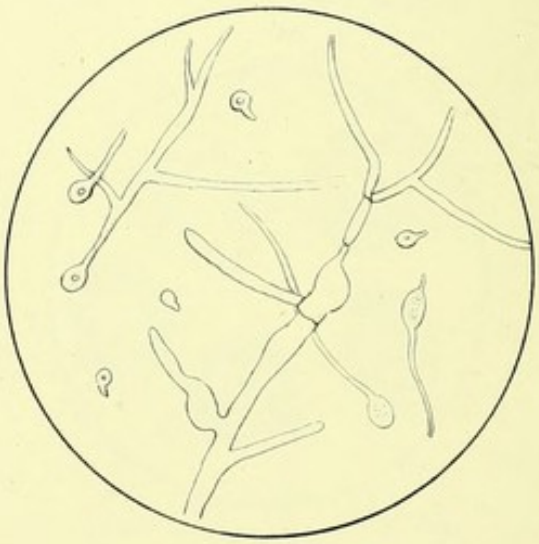

FIG. XVI. ×300
Spores germinating

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FIGS: XI–XVI. OBTAINED IN CHOLERA-STOOL
1000th of an inch ——— ×300

FIG. XVII. × 320

DEVELOPED IN A CHOLERA-STOOL

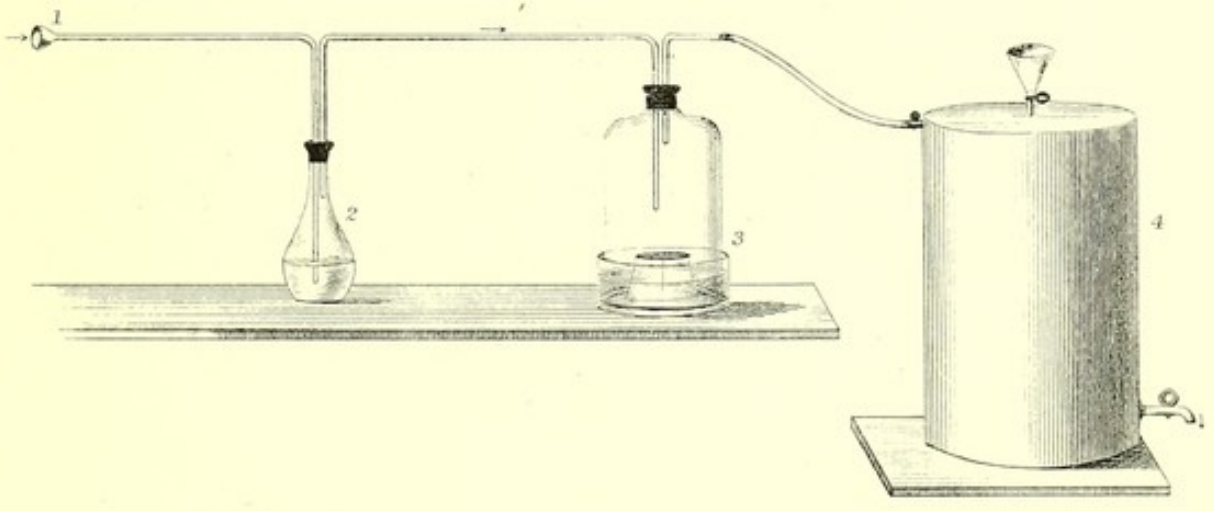

FIG. XVIII

THE ISOLATING APPARATUS

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FIGS. XVII – XVIII

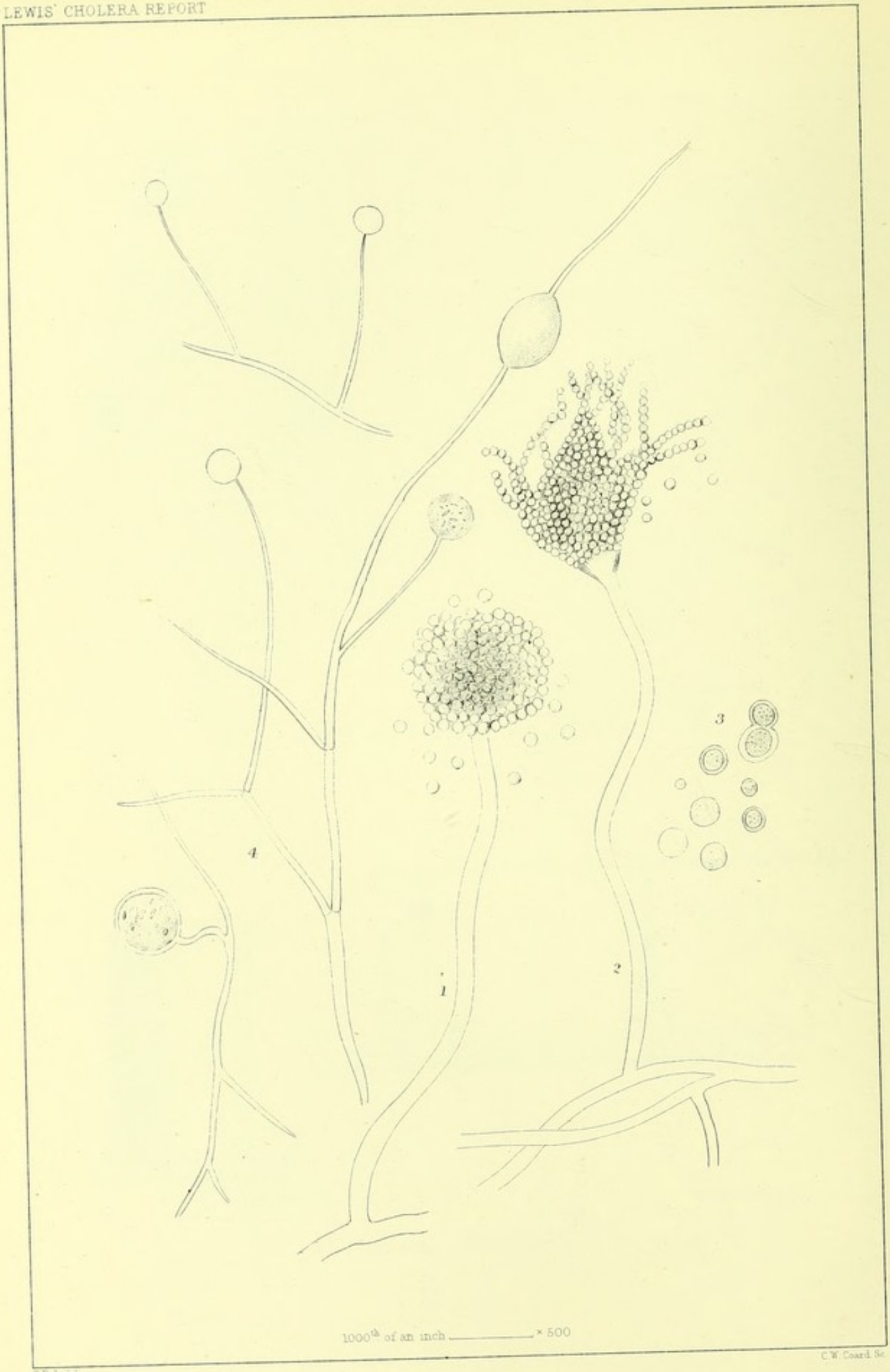

FIG. XIX. FUNGI DEVELOPED IN CHOLERA-STOOL

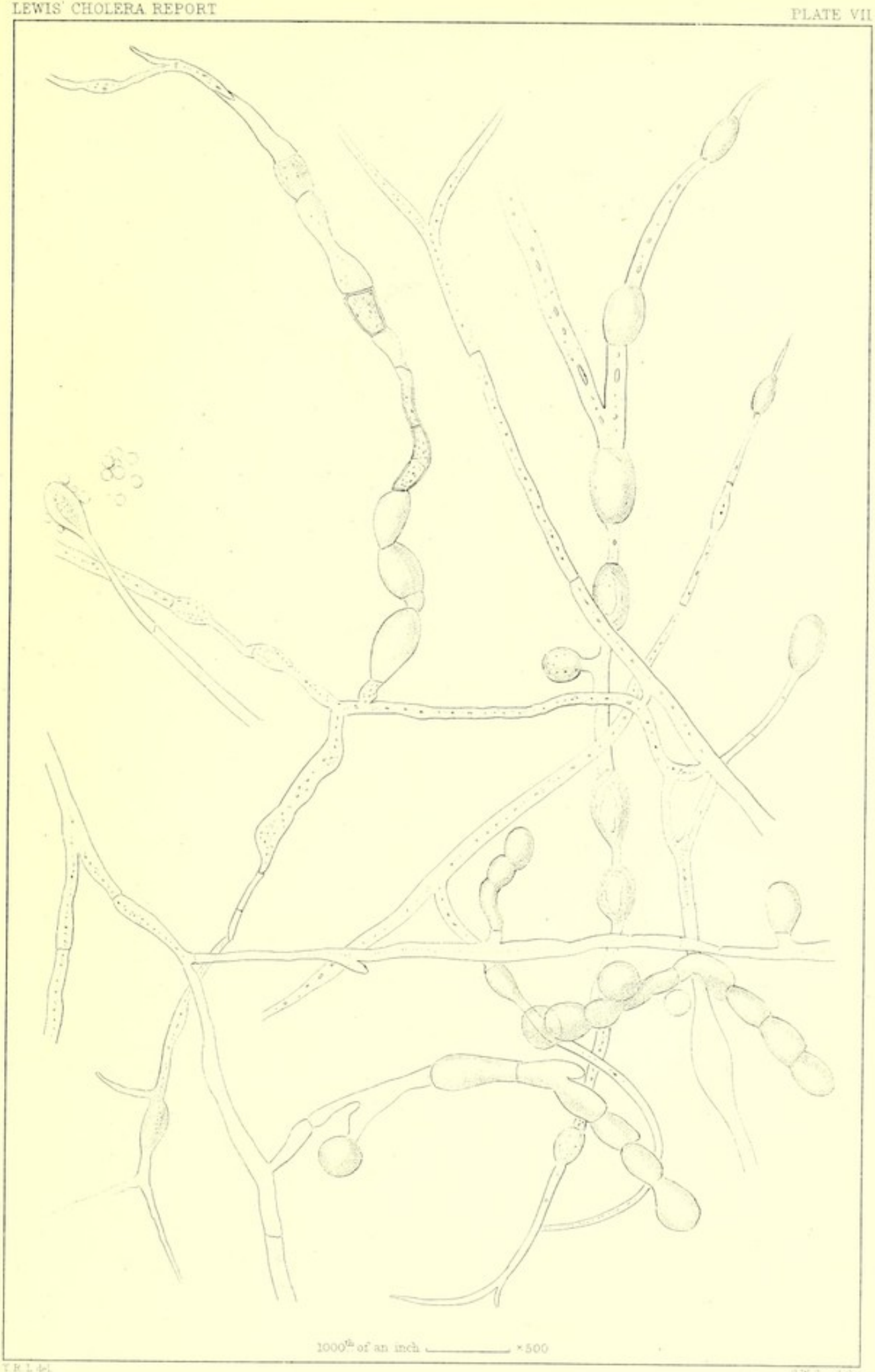

FIG. XX. MYCELIUM WITH MACROCONIDIA BUT WITHOUT SPORANGIA.
DEVELOPED IN CHOLERAIC DISCHARGE

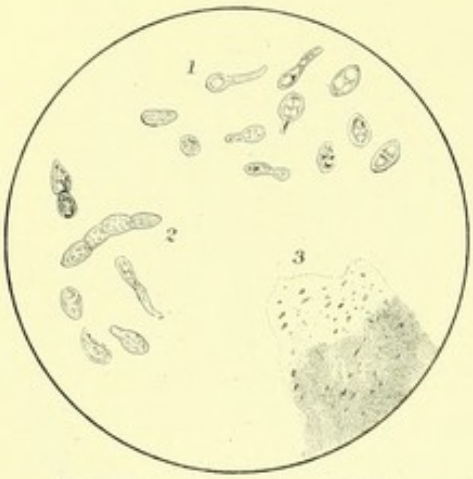

FIG. XXI. × 320

1. 2. Germinating Spores in ordinary stool
3. "Micrococcus"

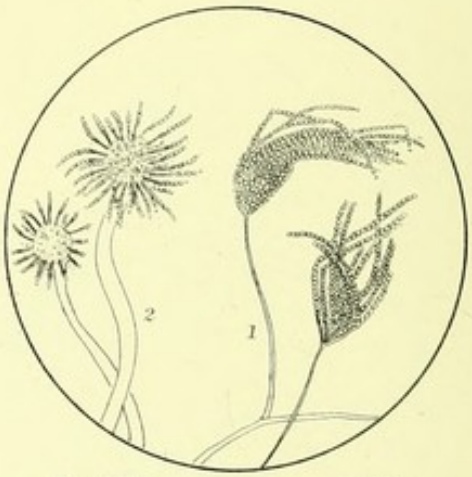

FIG. XXII. × 320

1. Penicillium
2. Aspergillus

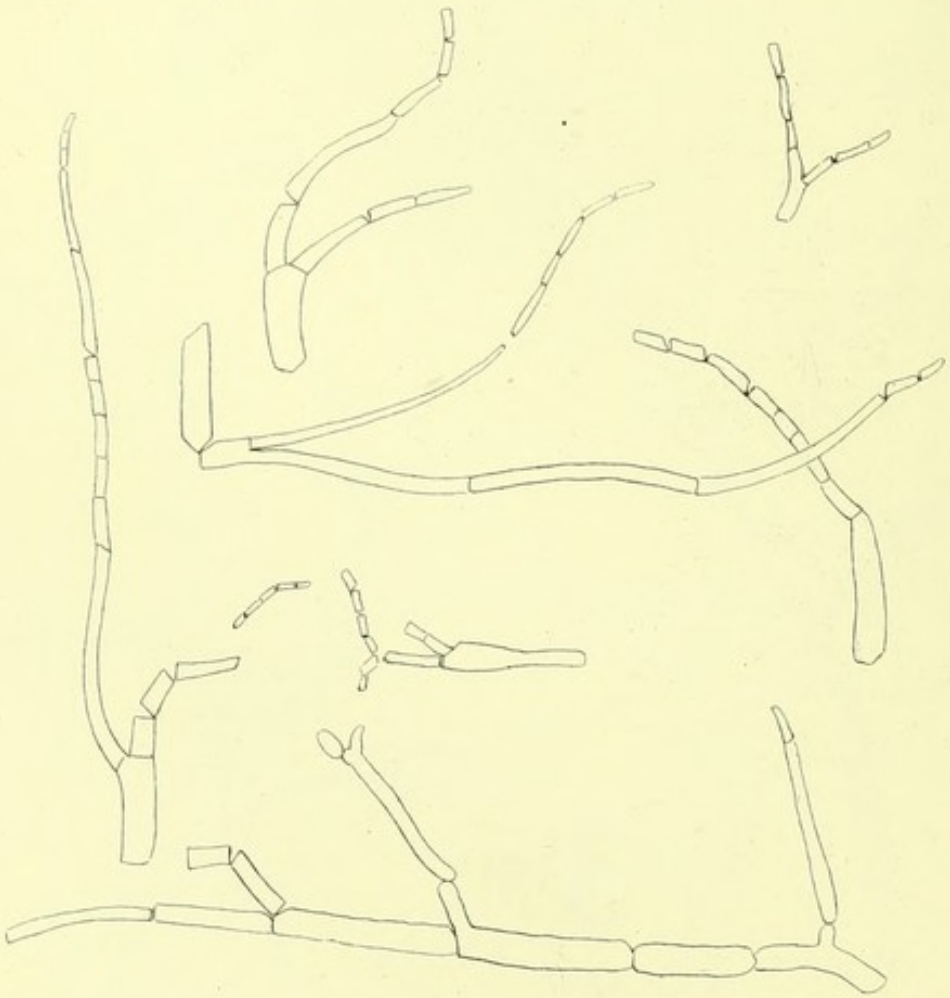

FIG. XXIII. × 320

OIDIUM LACTIS ("CHOLERA FUNGUS" of THOMÉ)

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FIGS: XXI–XXIII. DEVELOPED IN ORDINARY EXCRETA

1000 of an inch _____ × 320.

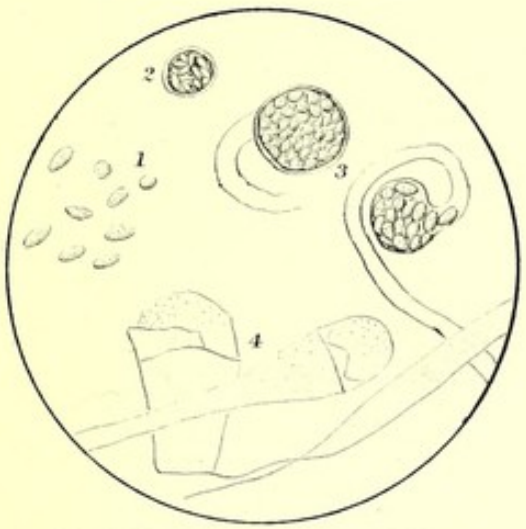

FIG. XXIV. ×320

(In a dry condition)

1. Spores escaped from Sporangium.
2. Cyst detached
3. Cysts attached to the fertile filament
4. Heads of filament with remains of Cyst
(Mucor)

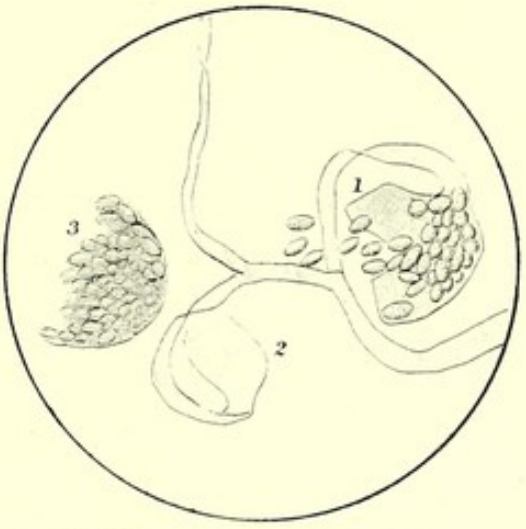

FIG. XXV. ×320

(Moistened with water)

1. Ruptured Cyst with Spores escaping
2. ——— ditto ——— Spores escaped
3. ——— ditto ——— detached from Stalk
(Mucor)

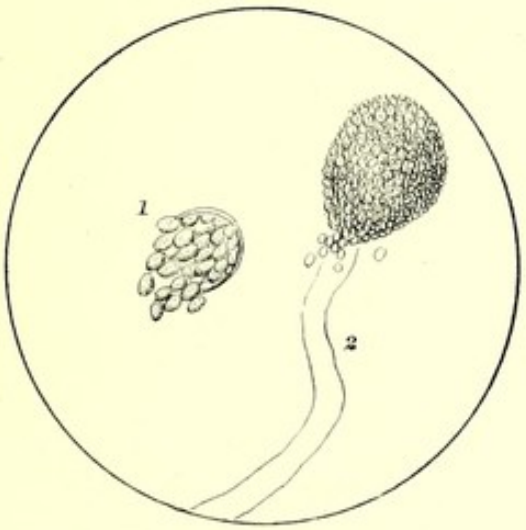

FIG. XXVI. ×320

(Moistened with water)

1. Sporangium fallen. Spores escaping.
(Mucor)

2. Aspergillus-head surrounded by a glutinous film, simulating a Capsule
(Aspergillus)

FIG. XXVII. ×320

(Moistened)

1.2. Same as XXVI-2
3. ditto germinating
(Aspergillus)

1000th of an inch ——— ×320

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CYSTS &c. SIMULATING HALLIER'S CHOLERA FUNGUS.
DEVELOPED IN ORDINARY EVACUATION.

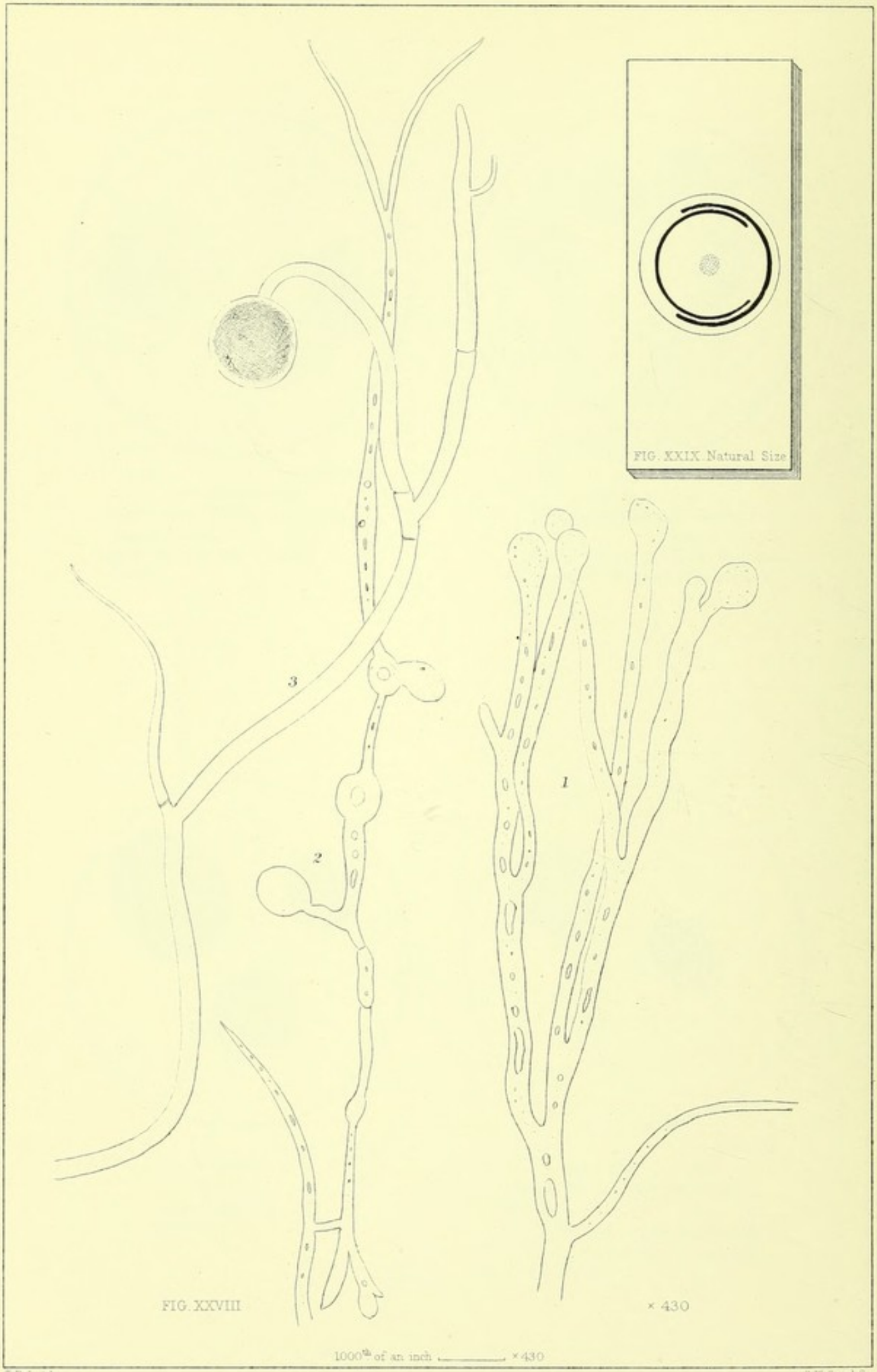

FIG. XXVIII. FUNGUS VERY LIKE HALLIER'S "CHOLERA FUNGUS."

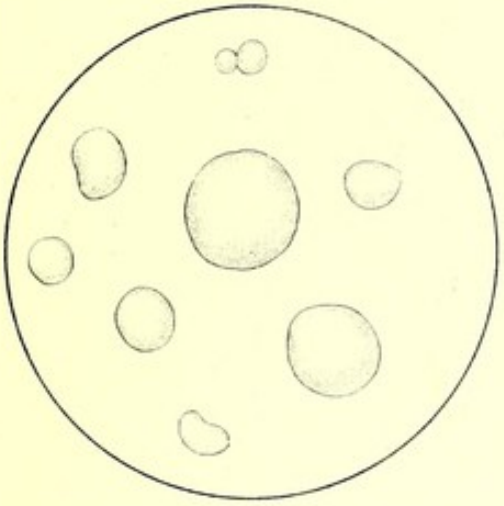

FIG. XXXI. ×600

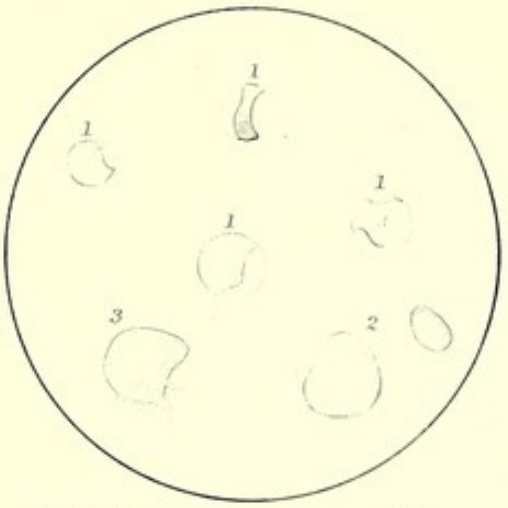

FIG. XXXII. ×600

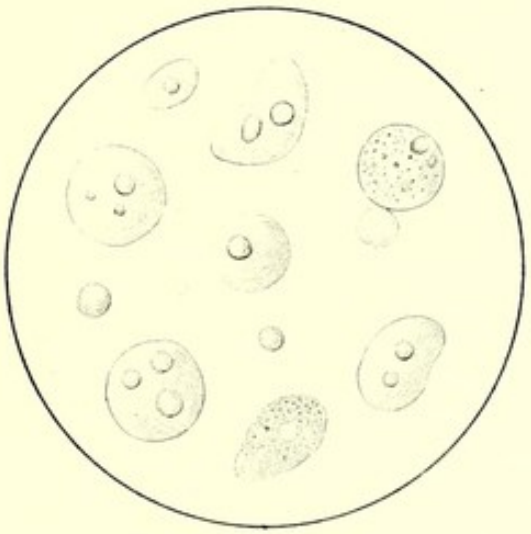

FIG. XXX. ×600

FIG. XXXIII. ×600

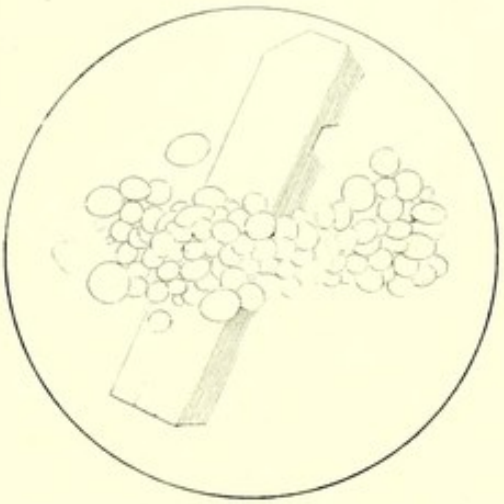

FIG. XXXIV. ×600

1000th of an inch. ×600

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FIGS. XXX – XXXIV. GLOBULES OF A FATTY NATURE
SIMULATING CYSTS, SPORES, &c.

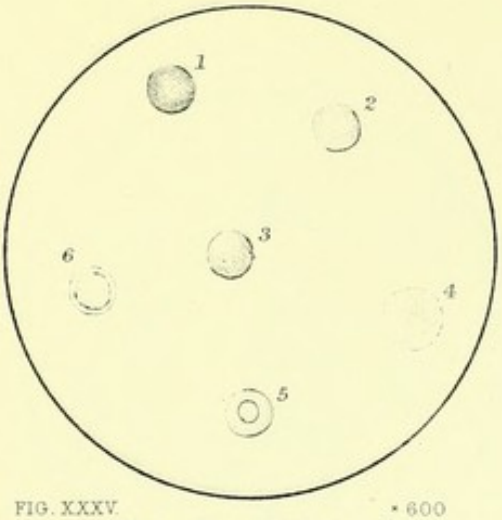

FIG. XXXV. × 600
Blood cells in a Cholera stool
Microscopic appearances of one cell

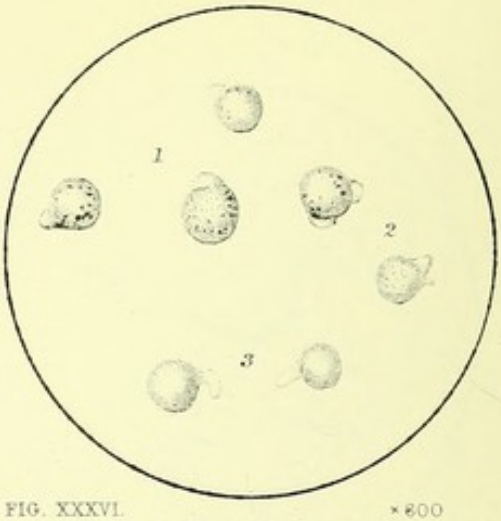

FIG. XXXVI. × 600
Blood cells in a Cholera stool.
1. With one protrusion. *2*. More than one
3. The protruded portion not retracted

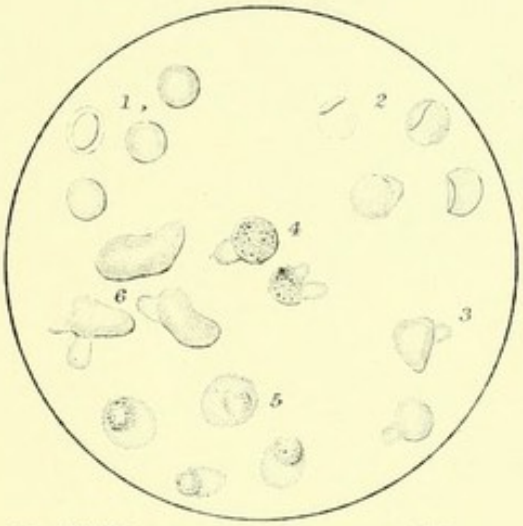

FIG. XXXVII. × 600
1.–*5*. Blood cells in "Chylous Urine"
6. Forms assumed by one large Corpuscle

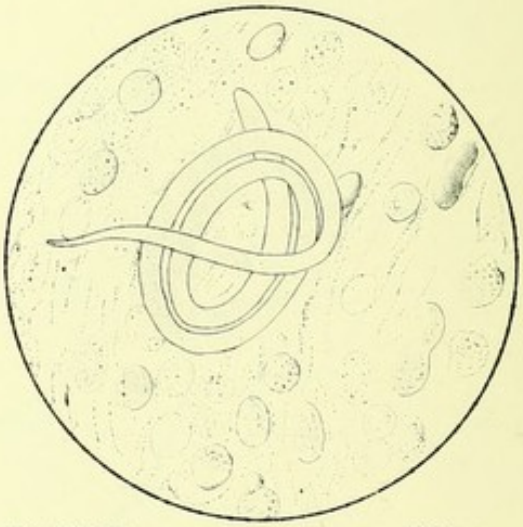

FIG. XXXVIII. × 600
Embryo of a Round Worm imbedded in gelatinized matter in "Chylous Urine"

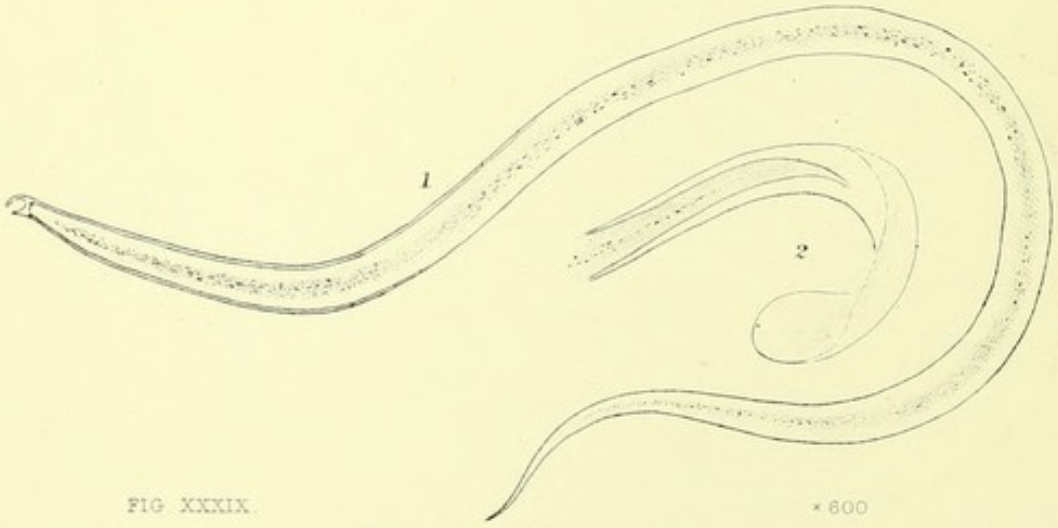

FIG XXXIX. × 600

EMBRYO IN "CHYLOUS URINE"
1. Immediately after addition of Acetic Acid
2. Tail of ditto after prolonged action of Acid

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FIGS. XXXV.– XXXIX.
1000th of an inch ——— × 600

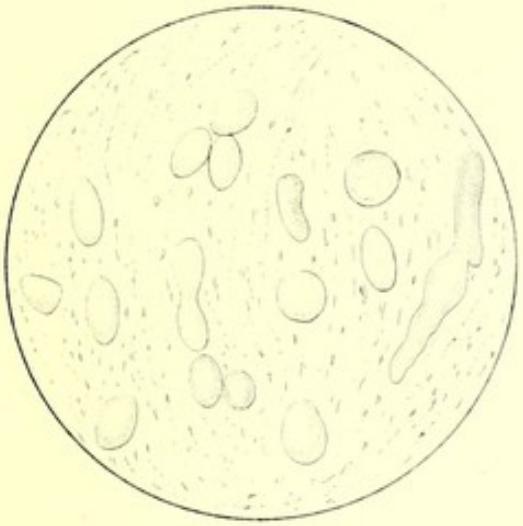

FIG. XL. ×600
Early condition of cells imbedded in the flakes

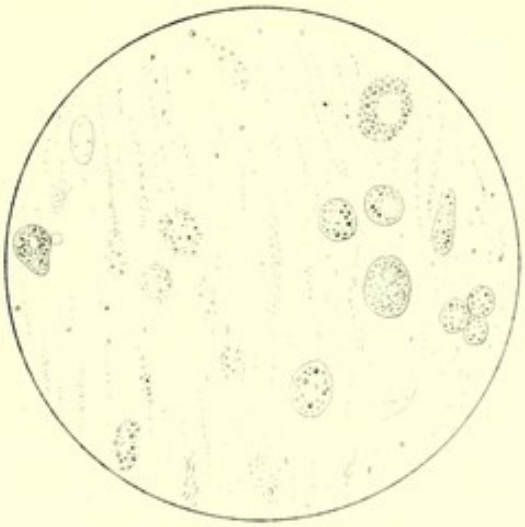

FIG. XLI. ×600
The same as XL. after 24 hours

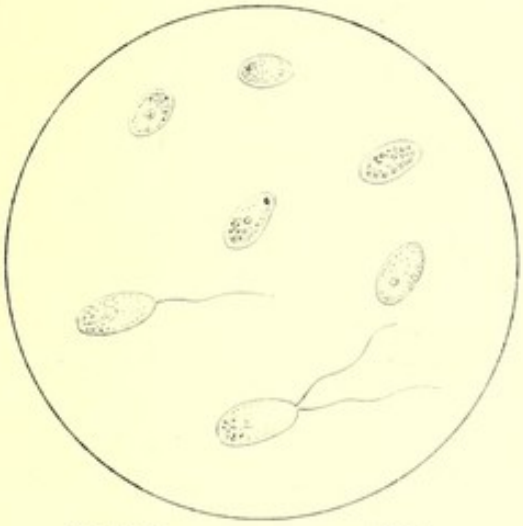

FIG. XLII. ×600
Animalculæ which appeared on 5th day

FIG. XLIII. ×600
Early appearance of granular condition of flakes

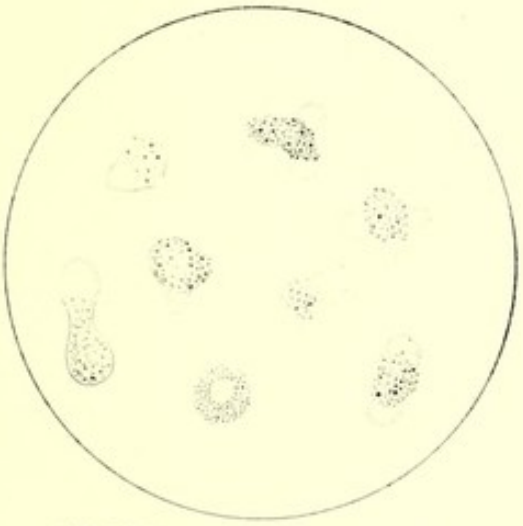

FIG. XLIV. ×600
Movements assumed by the Corpuscles associated with the Flocculi

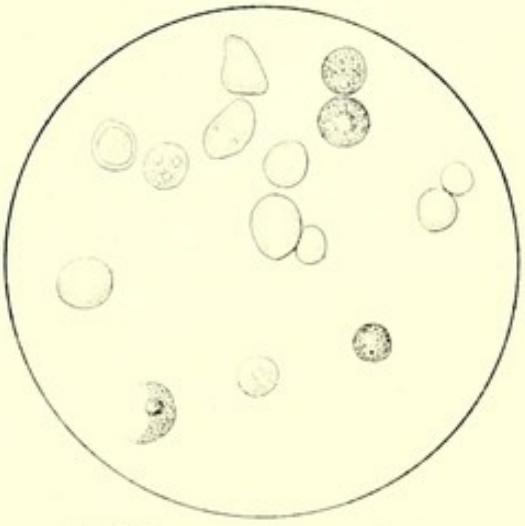

FIG. XLV. ×600
Appearance after addition of weak Acetic Acid and Iodine

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FIGS. XL – XLV. FLOCCULI &c. IN CHOLERA STOOL.

1000th of sq. inch ×600

FIG. XLVI. ×600
Corpuscles in the flocculi

FIG. XLVII. ×600
Effect of Iodine on the Corpuscles

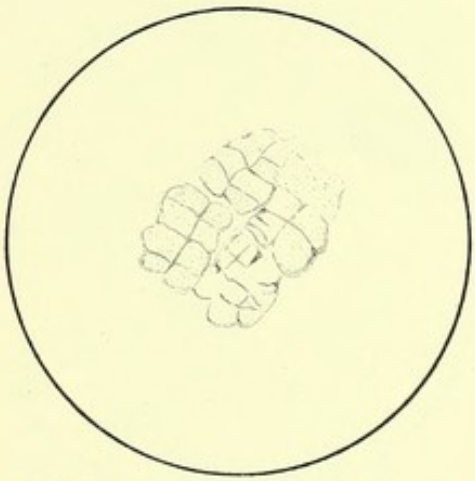

FIG. XLVIII. ×320
Sarcinæ in Cholera stool

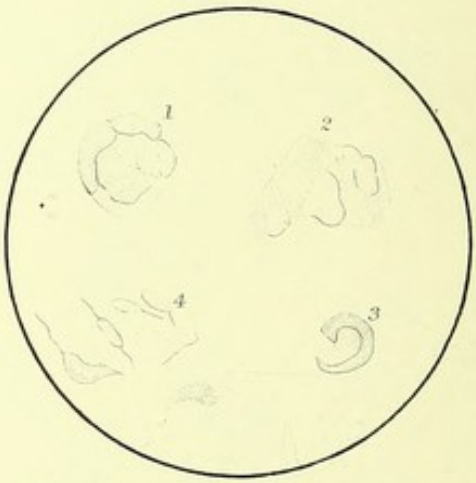

FIG. XLIX. ×320
1. Fatty masses
2–4 Animalculæ in various stages

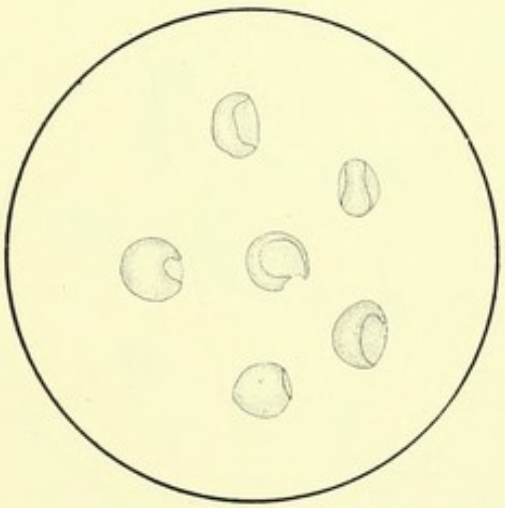

FIG. L. ×320
Various forms assumed by N°.3. Fig. XLIX.

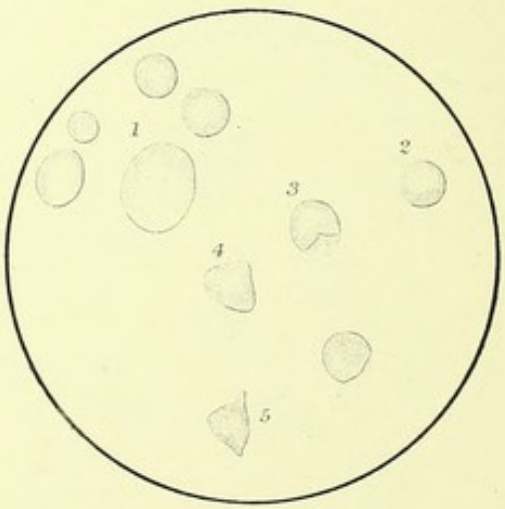

FIG. LI. ×320
1. Still condition of Animalculæ
2–5. Various forms assumed by one of the foregoing

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FIGS. XLVI – LI. VARIOUS OBJECTS IN CHOLERA STOOL

1000th of an inch ——— ×320

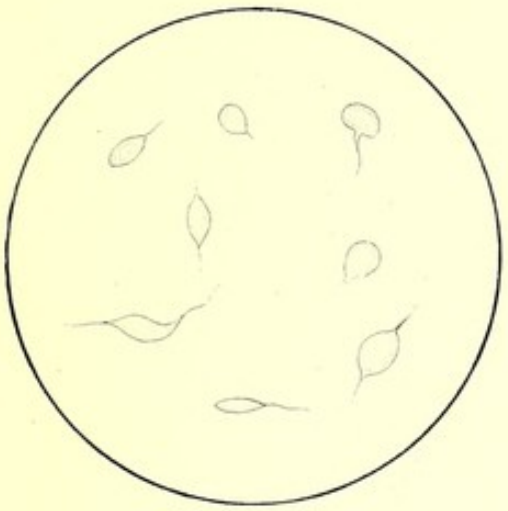

FIG. LII. ×430
Various forms assumed by the Animalcule

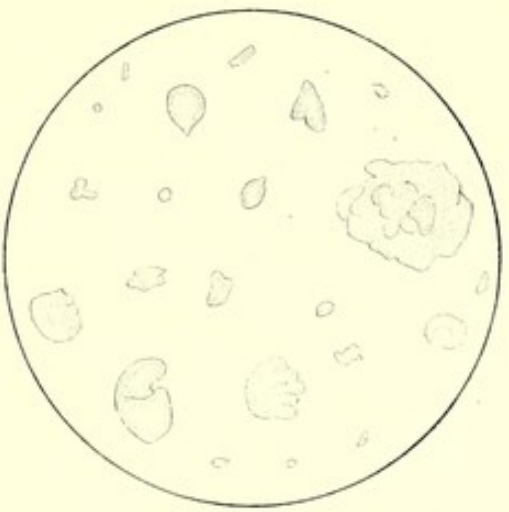

FIG. LIII. ×430
Gelatinous masses which replaced the objects in figs. XLIX–LII.

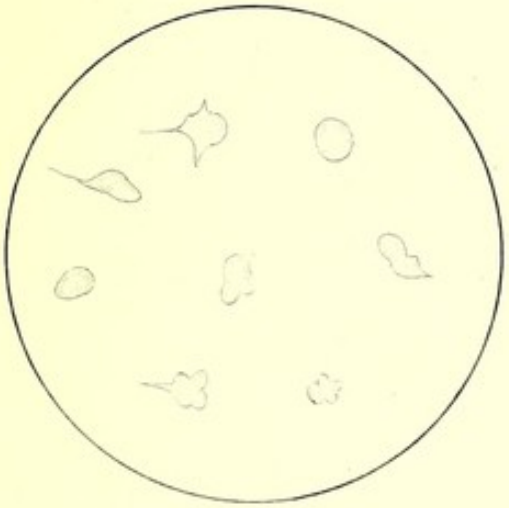

FIG. LIV. ×430
One Animalcule gradually becoming inactive

FIG. LV. ×430
Effect of re-agents on LIII. *1. 2.* Acetic Acid *3.* Absolute Alcohol. *4.* Ether & Alcohol

FIG. LVII. ×430
1. Animalcule still and granular *2.* Become amœboid on 2nd day afterwards active *(3)*

FIG. LVI.
Mr Berkeley's 'Growing-cell' (Natural size)

T. R. L. del. C. W. Coard Sc.

FIGS. LII–LVII. STAGES IN THE EXISTENCE OF THE ANIMALCULE
AND THE REVº Mr BERKELEY'S GROWING CELL
1000th of an inch ——— ×430.

FIG. LVIII. ×600
Large granular cells intermixed with Animalculæ in the active condition. (Cholera)

FIG. LIX. ×600
Same stool as LVIII.

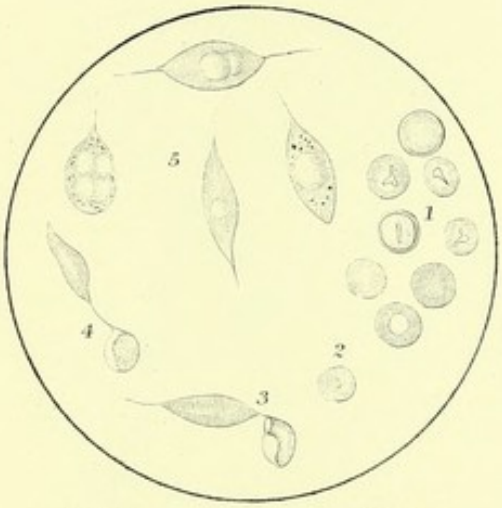

FIG. LX. ×600
Animalculæ altering the form of blood-cells *(1-4)*
5. Animalculæ with blood-cells attached.

FIG. LXI. ×600
Healthy blood-cells placed in some cholera stool, (filtered)

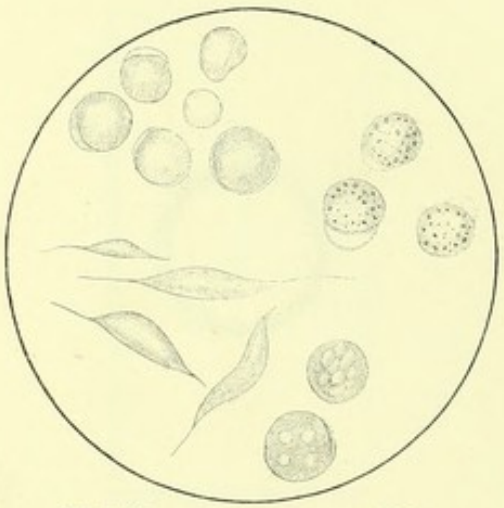

FIG. LXII. ×600
The Animalculæ &c. found in the stools of a healthy person.

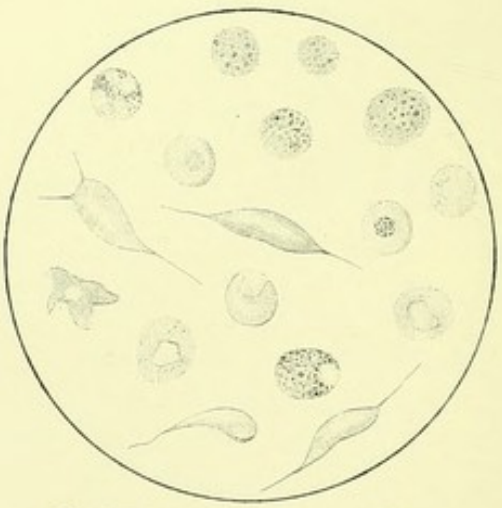

FIG. LXIII. ×600
Same as LXII. 24 hours later

1000th of an inch ×600

T. R. L. del. C. W. Coard. Sc.

FIGS. LVIII – LX. EXAMINATION OF CHOLERA STOOL
LXI " " HEALTHY BLOOD IN DITTO
LXII, LXIII " ORDINARY STOOL

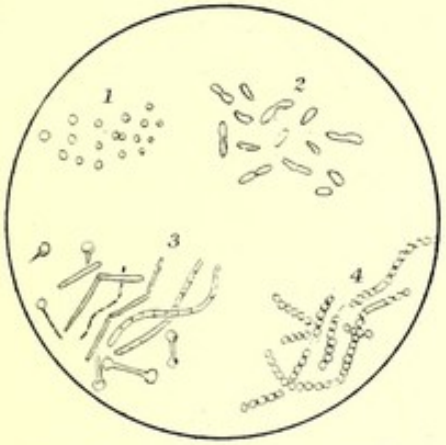

FIG. LXIV. ×500
1. Monads *2*. Bacteria
3. Vibriones *4*. Leptothrix

FIG. LXV. ×500
Developed in Organic Solution on 2nd day
(unboiled)

FIG. LXVI. ×500
Developed in Organic Solution 3rd day
Formation of "heaps"

FIG. LXVII. ×500
Developed on 5th day

FIG. LXVIII. ×500
Developed on 5th day

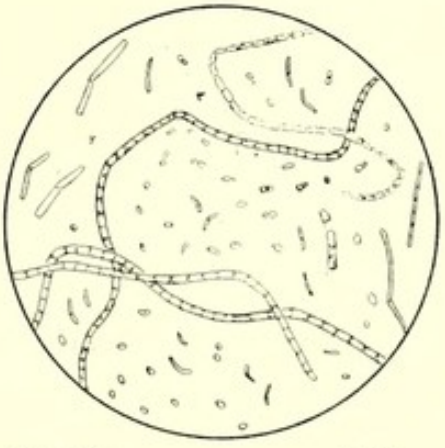

FIG. LXIX. ×500
Developed in boiled Organic Solution
3rd day

T.R.L. del. C.W. Coard. Sc.

FIGS. LXIV.–LXIX. DEVELOPMENTS IN ORGANIC SOLUTIONS

1000th of an Inch ———— ×500

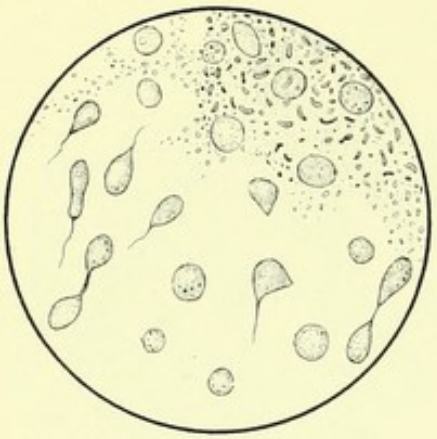

FIG. LXX. ×500
Developed in boiled Organic Solution.
3rd week

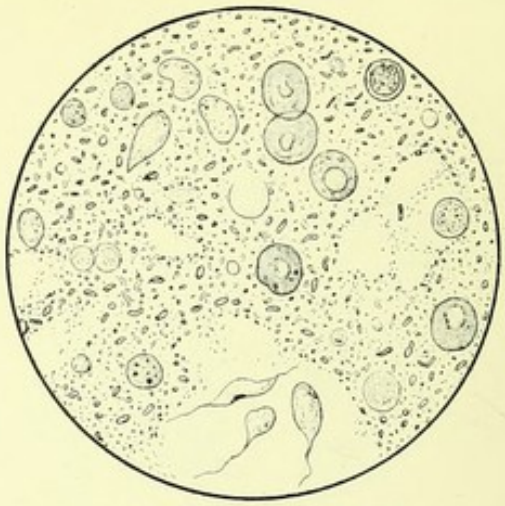

FIG. LXXI. ×500
As LXX. 5th week

FIG. LXXII. ×500
Developed in boiled Organic Solution, which had been breathed into 3rd Month.

FIG. LXXIII. ×500
As LXXII. Germinating.

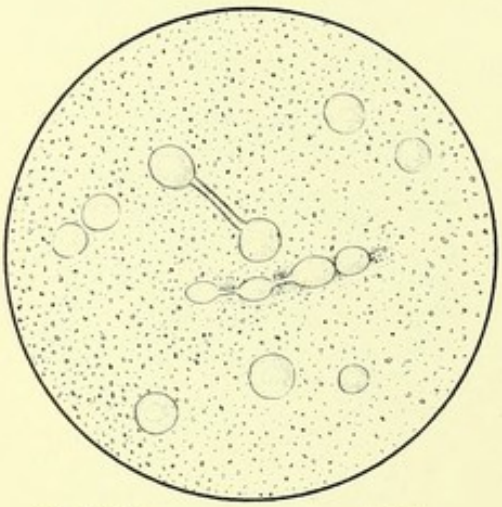

FIG. LXXIV. ×500
As LXXIII. with addition of Gum-water.

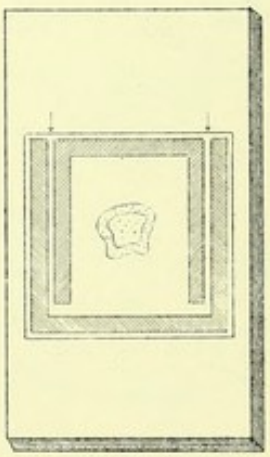

FIG. LXXV. Natural Size
Dr. MADDOXS CULTIVATING SLIDE

T. H. L. del. C. W. Cuard. Sc.

FIGS. LXX-LXXV. DEVELOPMENTS IN ORGANIC SOLUTIONS

1000th of an Inch ———— ×500

FIG. LXXVI. ×300

1. Various forms assumed by one *2.* Portions of its substance become detached. *(3)4.* Process of division *5.* Segmentation complete. *6.* A Vacuole appears in the detached portion.

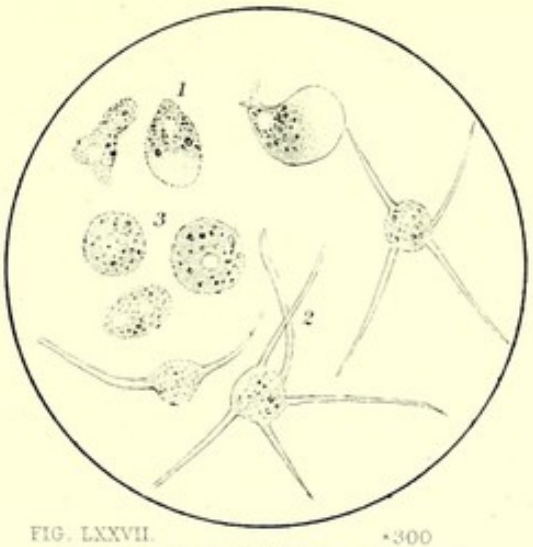

FIG. LXXVII. ×300

1. Amœbæ. *2.* Becoming Stellate on addition of water and finally circular *(3)*

FIG. LXXVIII. ×300

1. Contents discharged as granular filaments *2.* Molecules very active *3.4.* Disappearance of Amœba.

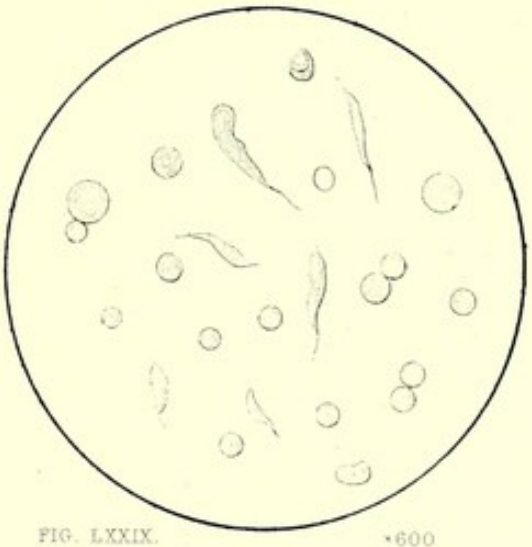

FIG. LXXIX. ×600

"Yeast-cells" and Anguillulæ?

FIG. LXXX. ×600

Development of Young Paramecia

1. Corpuscles developing in the midst of a "heap" *2.* Still further advanced. *3.* A contractile Vesicle formed. *4.* A freed Animalcule *5.6.* Irregular outline of Animalcule in thick fluid

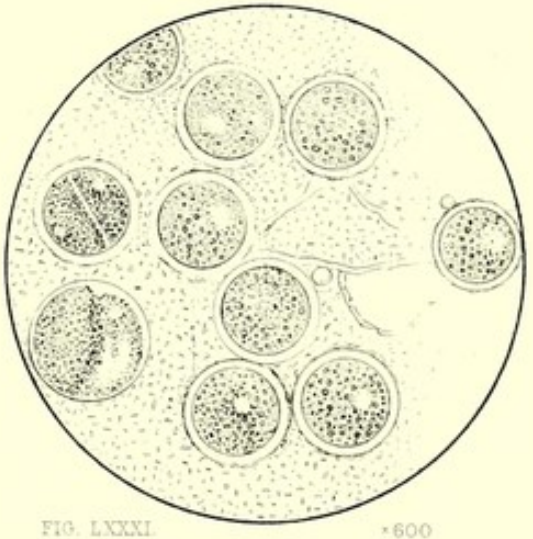

FIG. LXXXI. ×600

Encysted condition of LXXX. *4*

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FIGS. LXXVI – LXXXI. DEVELOPED IN SOLUTIONS OF ORGANIC MATTER

1000th of an Inch ——— ×300

——— ——— ×600

FIG. LXXXII. ×600
A young Paramecium getting out of the encysted condition

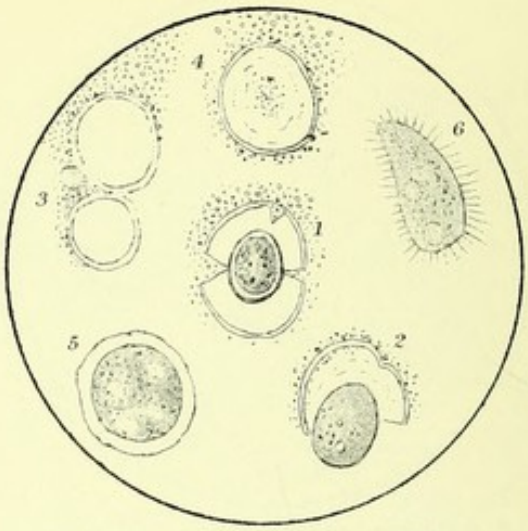

FIG. LXXXIII. ×600
1 Ruptured Cyst. *2*. Escaping Animalcule *3.4*. Empty Cysts. *6*. More highly developed Paramecium. *5*. Cyst containing four

FIG. LXXXIV. ×600
Still and active condition of the Animalculæ observed in Cholera-stool

FIG. LXXXV. ×600
Carmine added to LXXXIV.

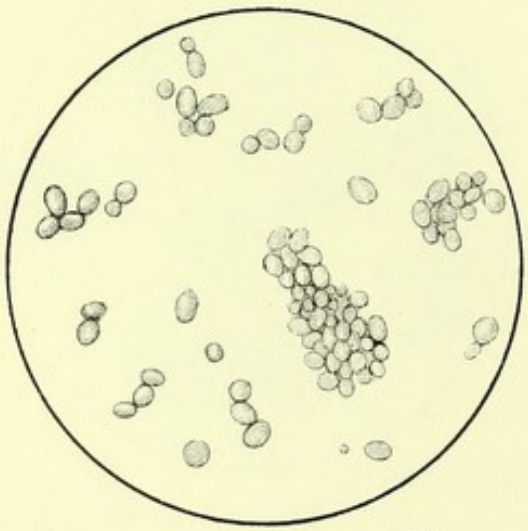

FIG. LXXXVI. ×600
"Yeast-cells"

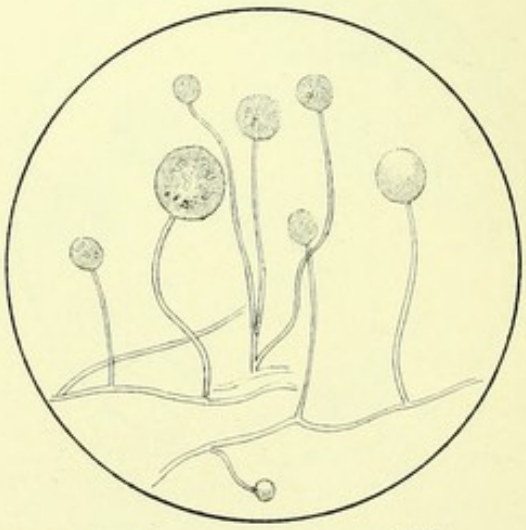

FIG. LXXXVII. ×600
Developed in Cholera stool

C. W. Coard, Sc.

C. W. L. del.

FIGS. LXXXII–LXXXVII. DEVELOPMENTS IN ORGANIC SOLUTIONS

1000th of an Inch ——— ×600

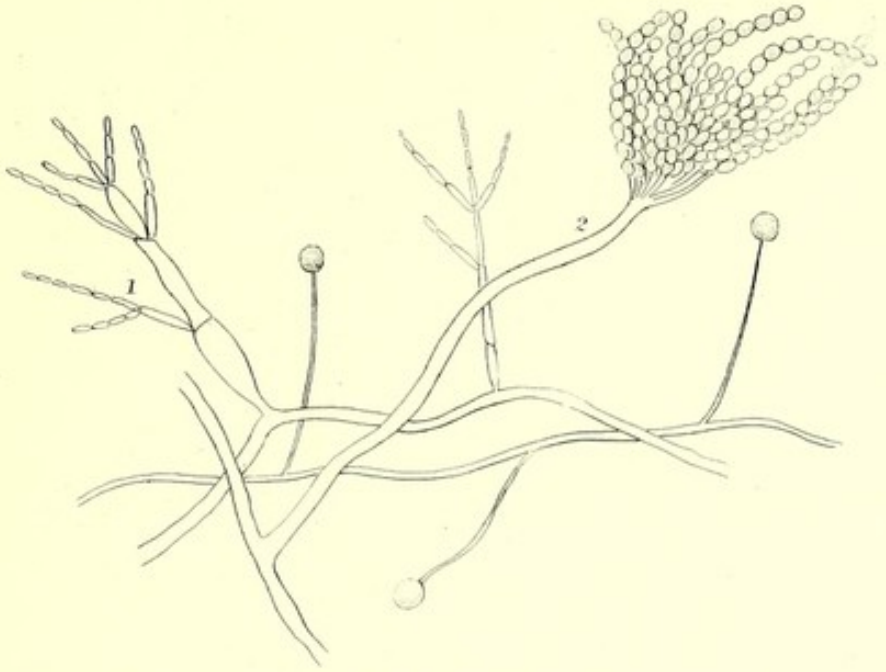

FIG. LXXXVIII. *1.* Penicillium Viride. *2.* P. Glaucum. ·600

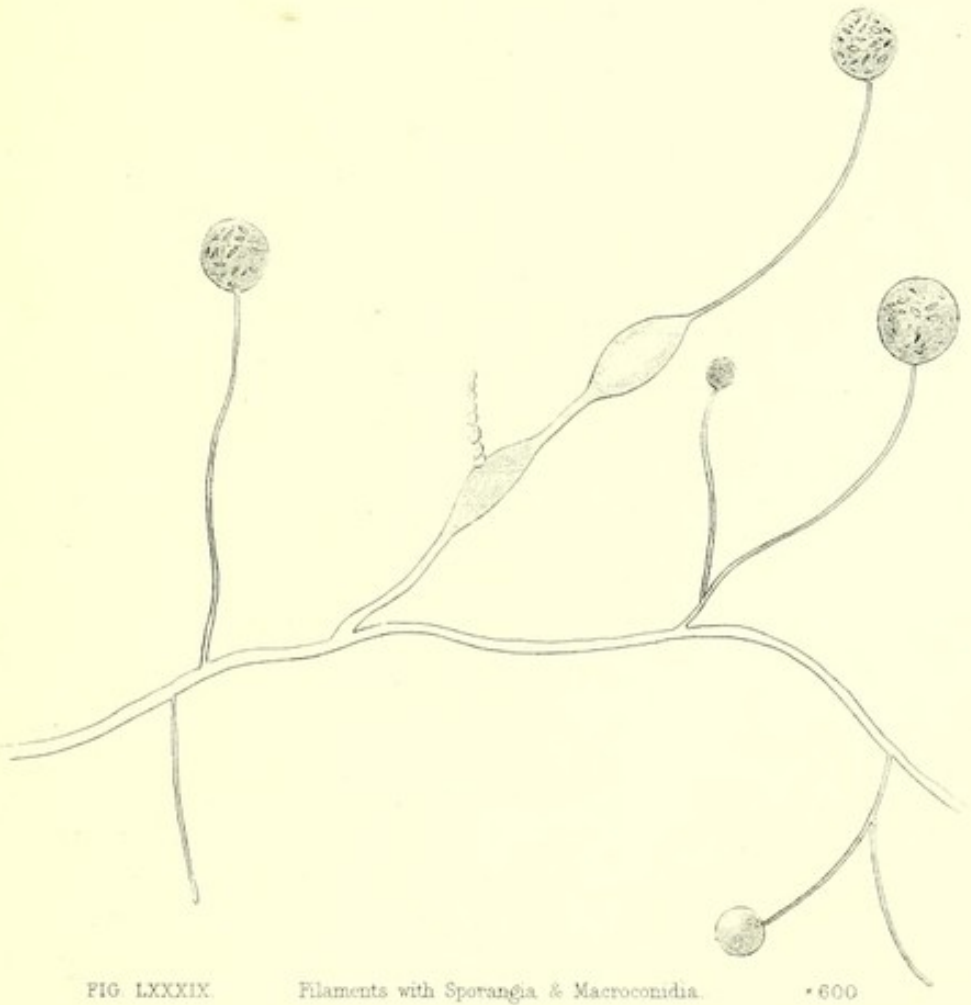

FIG. LXXXIX. Filaments with Sporangia & Macroconidia. ·600

T.R.L. del. C.W.Cuerd Sc.

FIGS. LXXXVIII-IX. DEVELOPED IN CHOLERA STOOL

1000th of an Inch ·600

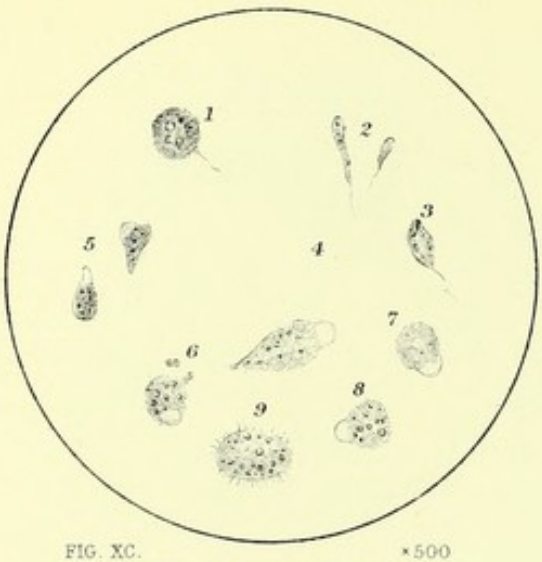

FIG. XC. ×500

1–8. Various stages of Monas lens
9. Young Paramecium.

FIG. XCI. ×500

Zoosporoids and Astasiæ

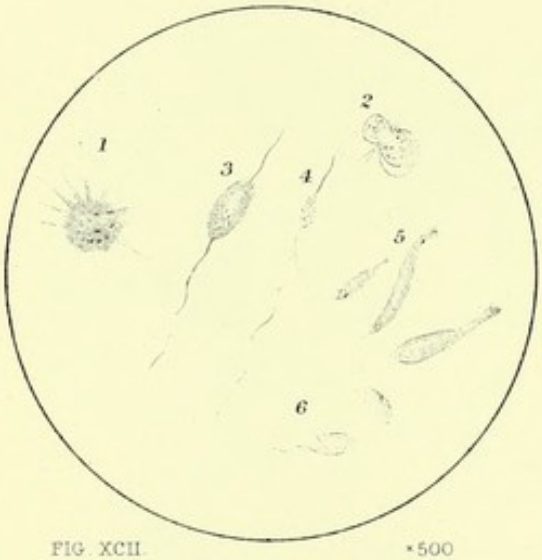

FIG. XCII. ×500

1. 2. Panophrys. *3. 4. 6.* Euglenæ or Astasiæ. *5.* Amphileptus.

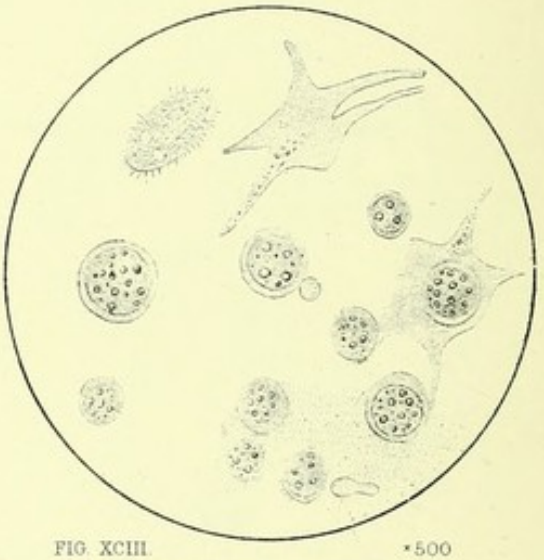

FIG. XCIII. ×500

Monera with encysted Animalculæ and one Paramecium

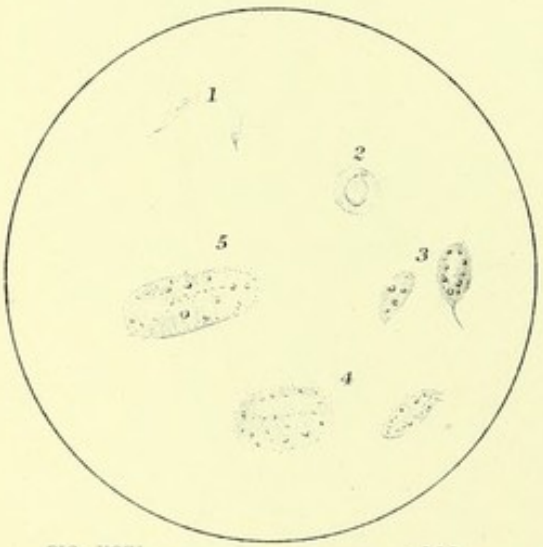

FIG. XCIV. ×500

1. 2. Zoosporoids. *3.* Monas lens
4. Paramecia? *5.* Coleps hirtus

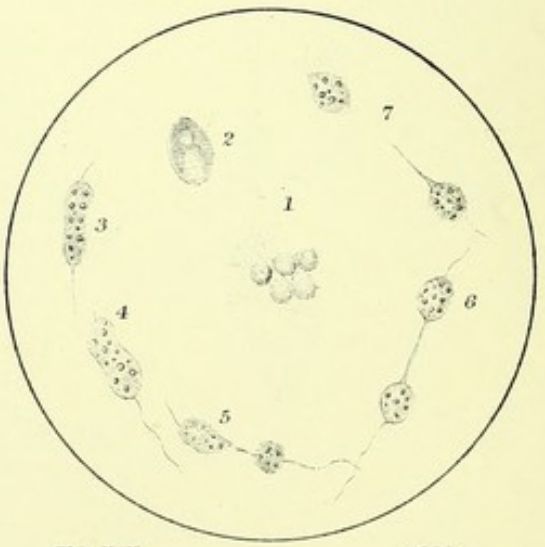

FIG. XCV. ×500

1. 2. Algæ
3–7. One Monas lens dividing into two

1000th of an Inch _____ × 500

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FIGS. XC–I. DEVELOPED IN MOISTENED SOIL FROM ALLAHABAD
XCII–III. LUCKNOW
XCIV. FYZABAD
XCV. MEERUT

FIG. XCVI. ×500
1-6. Various stages of Monas Lens
7-8. Euglenæ (?)

FIG. XCVII. ×500
1. Spores of Helminthosporium (?) *2-3* Monas Lens
4. Amæba various forms assumed by one

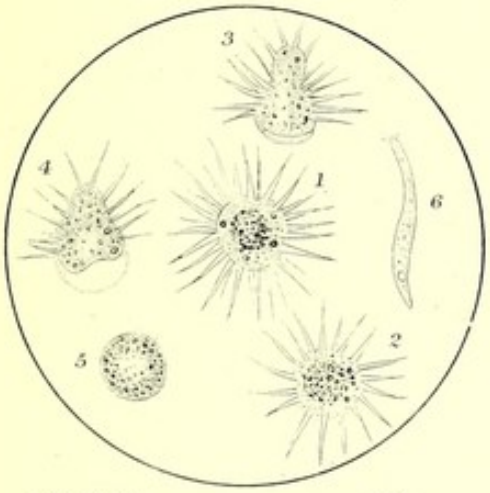

FIG. XCVIII. ×600
Various positions of one Panophrys *1-5*
6. Amphileptus

FIG. XCIX. ×600
1-4. A Paramecium dividing
5. Division complete

FIG. C. ×500
Monera.

FIG. CI. ×500
Moner with Vibriones

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FIG. XCVI. DEVELOPED IN MOISTENED SOIL FROM MEERUT
FIGS. XCVII-CI. PESHAWUR
1000th of an inch ×500

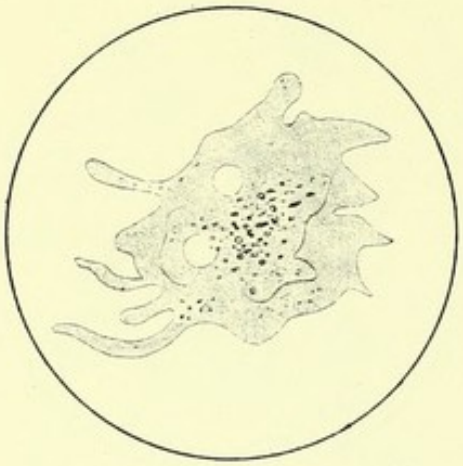


FIG. CII. ×800

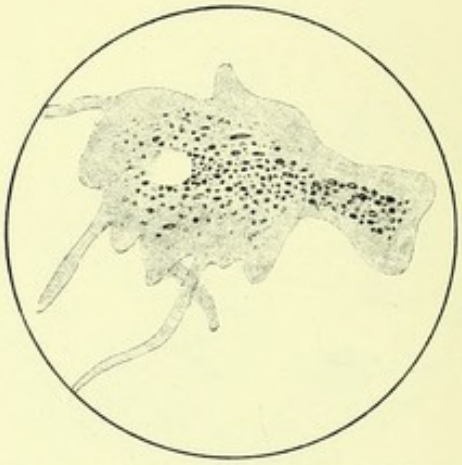


FIG. CIII. ×800

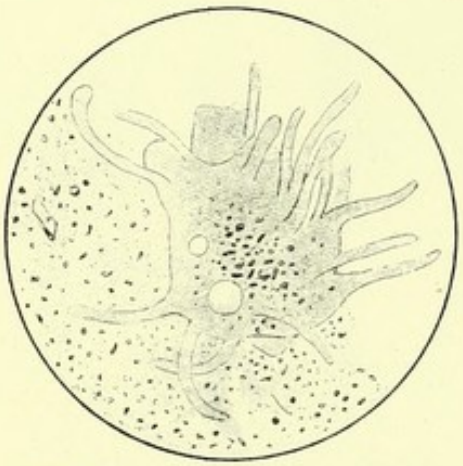


FIG. CIV. ×800

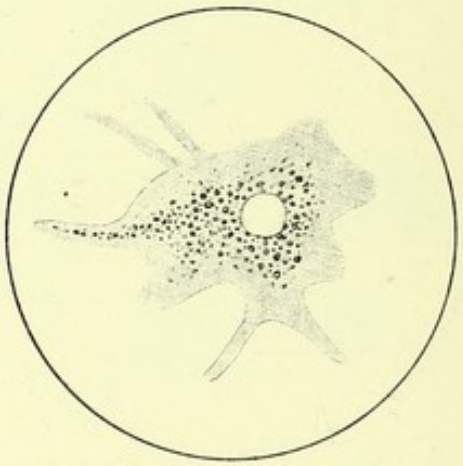


FIG. CV. ×800

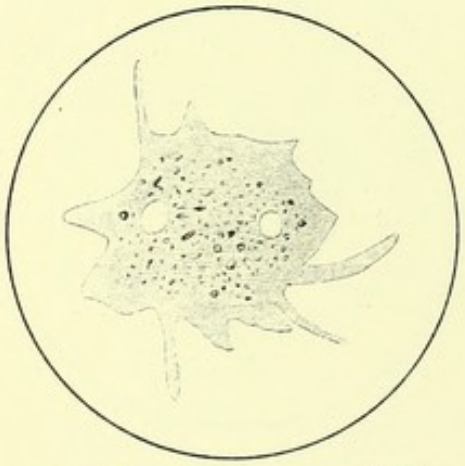


FIG. CVI. ×800

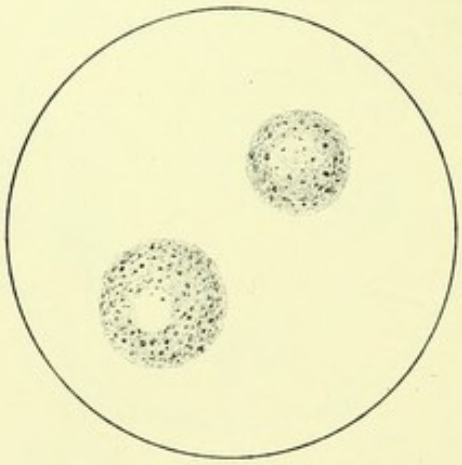


FIG. CVII. ×500

1000th of an Inch ×500 ×800

T.R.L. del. C.W. Coard Sc.

FIGS. CII-CVI DEVELOPED IN MOISTENED SOIL FROM PESHAWAR
VARIOUS FORMS ASSUMED BY ONE IN TWO MINUTES
FIG. CVII FOREGOING BECOME SPHERICAL & STILL

A REPORT

OF

MICROSCOPICAL AND PHYSIOLOGICAL RESEARCHES

INTO THE

NATURE OF THE AGENT OR AGENTS PRODUCING

CHOLERA.*

BY

T. R. LEWIS, M.B., AND D. D. CUNNINGHAM, M.B.

INTRODUCTION.

In the Instructions issued by the Army Sanitary Commission for the conduct of this inquiry, particular stress is laid on the importance of accepting no statement bearing on the question of the mode of origin and diffusion of cholera as proven, no matter how distinguished the authority on which it may have been made, until an opportunity occurred for verifying it for ourselves. It has been our endeavour to adhere strictly to this injunction, and we have therefore gone over ground on which, under other circumstances, it might have been considered unnecessary for us to enter. This, however, we do not by any means regret, as the experience gained by such a training has more than compensated for the time and labour expended on it. It has obliged us to be more on our guard than we might otherwise have been, especially in connection with observations that have been authoritatively put forth regarding some low forms of life, and of the interpretations which have been made concerning the effects of various experiments on lower animals.

We do not for a moment expect, nor do we wish that our own observations should be accepted in a different spirit; on the contrary, we should be glad to

*Being one of the Appendices to the eighth Annual Report of the Sanitary Commissioner with the Government of India, 1872.

see them practically tested by those who have the opportunity of doing so. The observations here recorded are submitted as facts; in no instance has an observation been included which had not been witnessed by both of us; any observation one may have made, which had not been verified by the other, has been allowed to stand over. The interpretation which we have ventured to put on some of these observations may of course be erroneous, but the facts have, to the best of our ability, been accurately recorded, so that no one need be led astray by any faulty inferences of ours.

We have, as far as possible, carefully avoided the introduction into the text of any descriptive terms involving the acceptance of a theory, although it would have been in some cases very convenient to have adopted some of the ingeniously coined words lately admitted into our medical vocabularies. To the authors of some of the terms which we have employed we are particularly indebted, and we wish specially to acknowledge the aid we have received from a study of the writings of Professors Beale, Burdon Sanderson and Bastian.

Our report has been divided into three parts; the first containing a description of the microscopical appearances of the blood in cholera; the second giving an account of a series of experiments on the action of solutions of organic matter from various sources and in various stages of decomposition on living animals; and the third, on the effect of section of certain nerves.

I. MICROSCOPIC EXAMINATIONS OF HUMAN BLOOD.

A.—Results of microscopic examinations of the blood in cholera, together with a description of the methods adopted.

ALTHOUGH results of careful examinations of the chemical characters of the blood in cholera have been frequently made, investigation of the microscopic characters presented by it, and more especially of the changes and developments occurring in it when removed from the body, has been comparatively neglected. As the subject is one of very great importance, and is daily becoming more so on account of the ideas now prevalent regarding the disease, it has been carefully investigated, and the general results, attained from numerous series of experiments, are briefly stated below. Any system of examination not allowing of prolonged and continuous study of individual specimens of blood, as well as of exact observation of their characters when first removed from the body, is necessarily unfitted to furnish trustworthy information, and before entering on the subject, it became necessary to devise means suited to the attainment of both these ends by making *continuous* examinations of the blood.

The requirements of the case appeared to be sufficiently met by adopting the following methods for the immediate examinations of blood. Specimens of blood were placed under thin covering-glasses, individual specimens being prepared without any re-agent, mounted in acetate of potash after exposure to the vapour of a two per cent. solution of osmic acid, or mounted in acetate of potash or acetate of soda without previous exposure to the osmic fumes.

For continuous observations on the changes taking place in the blood after its removal from the body, wax-cells were employed. A small drop of blood having been received on the centre of a carefully cleaned covering-glass, the latter was pressed down on the wax-cell and hermetically sealed. The cell was deep enough to prevent the blood coming in contact with the slide, and therefore allowed of its free exposure to the included air.

This form of wax-cell is a modification of that employed by Stricker in similar investigations on the blood, and is identical with that described by Berkeley as specially adapted for observations on the development of fungi. The great advantage of the method is, that, when once the specimens have been carefully sealed, large numbers of cells may be retained in perfect condition for examination without calling for the employment of the moist chamber and its inherent fallacies, arising from the constant possibility of the introduction of extraneous elements into the material under observation. The effect of any such cells in facilitating observation may be judged of by the fact that by their means specimens of blood have been kept in a condition for continuous observation for nearly three months at a time. That sufficient air is included in them to allow of developments taking place in the isolated droplet of blood may be demonstrated by the results of certain observations to be hereafter referred to.

The specimens of blood during life were generally derived from the point of one of the fingers of the patient (which had been carefully washed with spirit or clean water and thoroughly dried) by pricking it with a needle. Those after death were usually obtained from one of the chambers of the heart.

Having briefly explained the methods which have been adopted in carrying out these observations, we now proceed to a description of the results obtained under these conditions.

1.—*Appearances presented by the blood, when treated with osmic acid and acetate of potash.*

In osmic acid preparations of cholera blood the red corpuscles appeared unaltered in most cases; in one or two they conveyed an undefined impression of softness. Few leucocytes were present as a rule, but in one specimen they were present in some numbers, along with other cells of considerably larger size and extremely delicate in outline and structure. Not the faintest trace of bacteria was detected

during life in any instance, although they were carefully searched for under powers ranging from the $\frac{1}{4}$ to the $\frac{1}{12}$ *à immersion.**

There were, however, as a rule, numerous specimens of minute irregularly rounded bodies giving a refraction like that of the leucocytes, and varying considerably both in size and form. They occurred sometimes in little patches or heaps, and in other cases, were irregularly scattered over the field. No structure could be detected in them, and they appeared to be mere fragments or particles of bioplasm (See Plate; Fig. 1).

All these bodies, red cells, leucocytes and minute bioplasts, were spread out in a medium precisely similar to that observed in normal blood, when prepared with osmic acid, almost homogeneous, in some places very finely molecular, and marked by faint delicate curved lines.

Preparations of blood obtained after death and treated in the same way presented precisely the same features. The only characteristic distinguishing them from the most healthy blood, was the presence of numerous bioplastic fragments described above, and even this did not appear to be constant. Any discussion of the probable nature of these bodies will be better deferred until a description of the changes occurring in the blood have been described.

Specimens of blood to which no re-agent had been added, and others treated with acetate of potash or acetate of soda, only differed from those treated with osmic acid in showing the minute bioplastic bodies less constantly and distinctly.

2.—*Appearances presented by specimens of blood in wax-cells.*

When examined immediately after preparation, and perfectly recent, these, as a rule, presented nothing noteworthy or in any way characteristic. In one or two instances the serum was stained with the colouring matter of the red corpuscles, but in general it was perfectly clear, free of staining and molecules or particles. The serum at first appeared as a very narrow ring around the corpuscles, but, as a rule, this rapidly widened as the mass of the latter contracted, and ultimately it formed a wide clear area of fluid around the clot. The number of white corpuscles at first visible was small and not noteworthy, but with the formation of the ring of clear serum a series of most remarkable phenomena gradually presented itself. Normal sized white corpuscles began to migrate into the fluid, but in addition to these, and in far greater numbers and activity, were much larger and more delicate bioplastic bodies; cells they were not, for they had not at this time the faintest differentiation of wall, contents, or nucleus. They were simply masses of fluid

* Latterly a $\frac{1}{25}$ objective by Powell and Lealand was employed, but we confess that, notwithstanding the most careful corrections being made for thickness of covering-glass, etc., we found it practically inferior to the $\frac{1}{8}$ and $\frac{1}{12}$ *à immersion* of Ross. We are, however, in daily expectation of a $\frac{1}{16}$ objective by the former distinguished makers, a glass having the reputation of being the most perfect hitherto constructed.

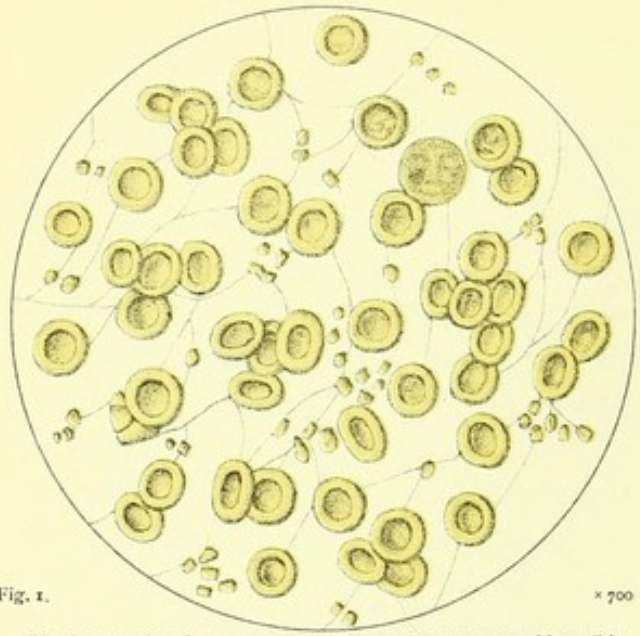


Fig. 1. × 700

Blood corpuscles after exposure to Osmic-acid fumes; one white cell is seen, with numerous fibrinous (?) threads, dotted with plasma particles.

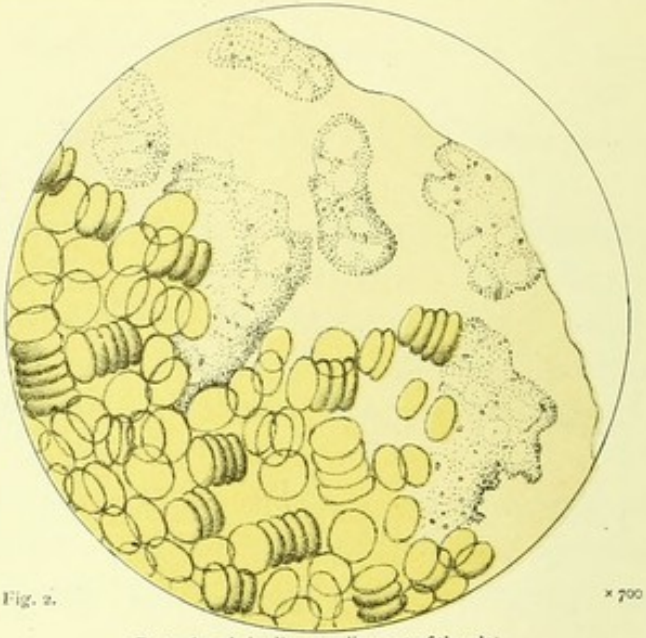


Fig. 2. × 700

Protoplasmic bodies crawling out of the clot.

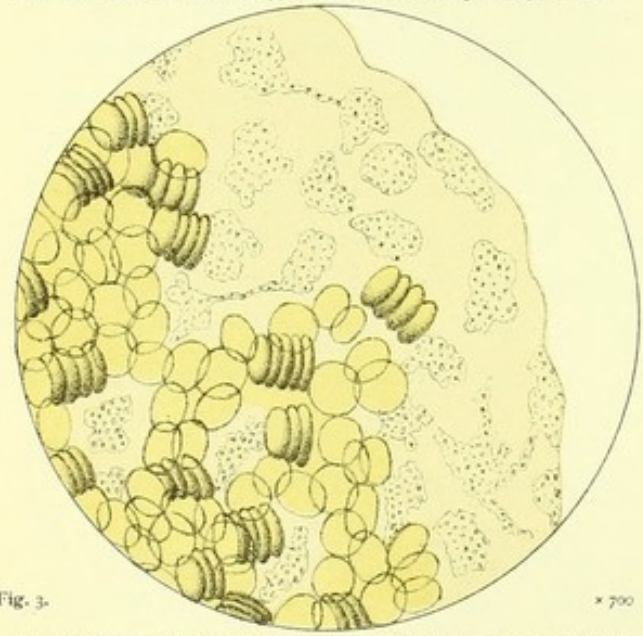


Fig. 3. × 700

The smaller portions of active protoplasm resulting from the sub-division of the bodies in Fig. 2.

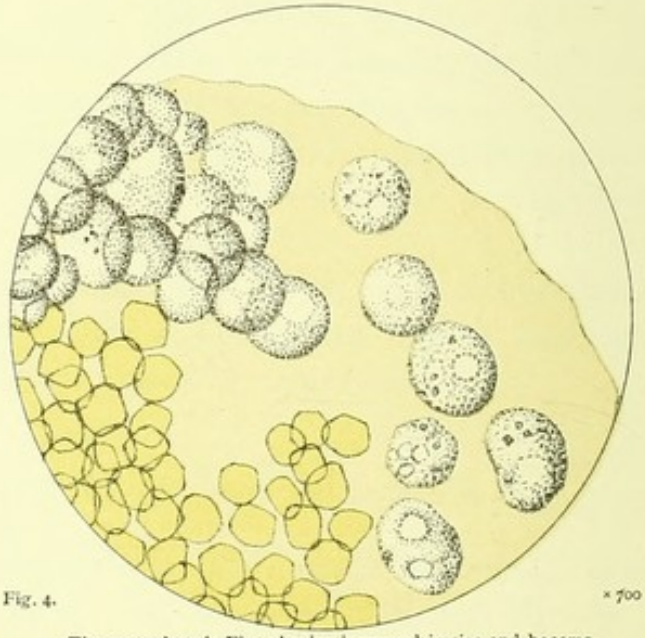


Fig. 4. × 700

The protoplasts in Fig. 3 having increased in size and become spherical, motionless, and more or less distinctly vacuolated.

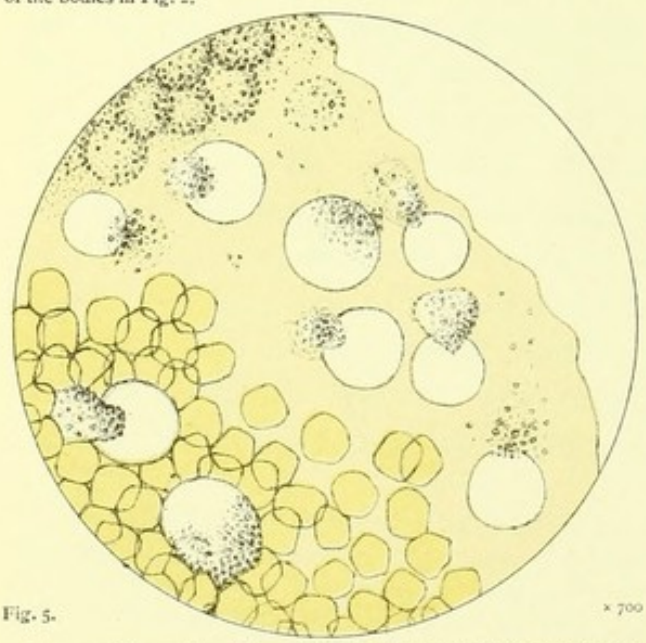


Fig. 5. × 700

Escape of the contents of the motionless corpuscles, with the appearance of hyaline capsules, and the formation of spherical aggregations of granules.

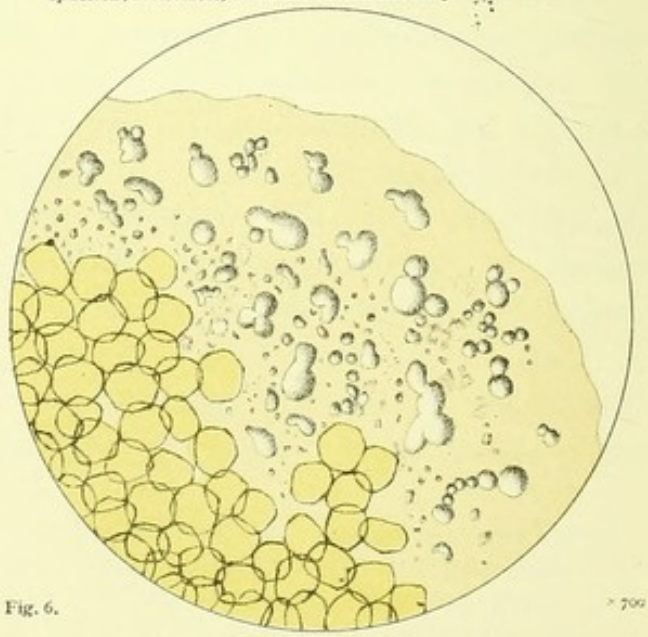


Fig. 6. × 700

Appearances resulting from the disintegration of the protoplasmic bodies.

CHANGES OCCURRING IN PREPARATIONS OF THE BLOOD IN CHOLERA.

bioplasm—bioplasm so fluid and diluted as in many instances to be almost, if not entirely, indistinguishable by refraction from the surrounding medium. But changes gradually take place in the recent blood. Again and again, has a patch of scattered granules been noted moving in unison across the field, and only after prolonged examination and most careful management of the light has it appeared that the individual granules were really included in a portion of bioplasm and were moved by its movements only. Gradually the consistence of these large bioplastic masses appears to increase, and they, as it were, grow into sight (Fig. 2). Their movements are extremely constant and free, no mere alterations of form, but free progression, along with such movements. The alterations in form vary extremely, sometimes consisting of the emission of rounded and lobulated protrusions, and at others of the running out of elongated slender extensions and threads.

Coincidently with the appearance of these bodies in the marginal serum, others of a similar nature may be observed in the serous spaces in the clot, and at this time also, in some cases, an abundance of small refractive bioplasts may be detected in the same localities. These small bioplastic bodies have seldom been seen to move or alter form, and, save slight increase in size, have not been observed to undergo any change, and seem shortly to disappear. In a few instances also the interspaces of the clot are occupied by very delicate branched fibrillæ, but this is by no means a constant or characteristic phenomenon.

Concerning the nature of the masses of plasma which have crawled out of the clot, the question arises—are these large masses of bioplasm the results of very rapid new development, or are they present in the blood from the beginning, but so fluid and so closely approaching the surrounding medium in density as to be indistinguishable until rendered somewhat firmer by changes occurring in them, induced by altered temperature of the medium or slight chemical changes in it, or unless they come to contain granular matter? At the close of an hour after the blood has been drawn, they are to be found in abundance crawling free in the serum and issuing from the edges of the clot. It is possible that the irregularly rounded particles in the osmic preparations may be due to the breaking up of these bodies, and the subsequent condensation of the substance of the bioplastic fragments resulting from the rupture. For a short time the ring of serum, and the serum above the clot, is full of these large irregular masses of bioplasm, moving freely in all directions. Soon, however, they begin to sub-divide and break up into a second generation of bioplasts (Fig. 3). The process of division can be seen most distinctly, sometimes occurring rapidly and, so to speak, decisively; whilst at others, after the two secondary bodies are widely separated, and only connected by a very slender, barely visible thread, one is retracted and, as it were, absorbed into the mass of the other, to be succeeded by one or more similar protrusions, ere division fairly takes place; the serum now swarms with multitudes of bioplasts of smaller size than those originally present, but resembling the previous generation in their delicacy of outline and great activity.

The bioplasts may frequently be observed at the edge of the rim of serum crawling along it, and, as it were, moulded to the curve of the marginal fluid (Fig. 3).

The period of extreme activity varies considerably, but, as a rule, at the close of twenty-four hours from the commencement of the observation, only a few remain freely motile, and the majority have considerably increased in size (Fig. 4). Towards the close of the freely moving, amœboid period, the density and refractiveness of the bioplasts increase, and there is an increase in the number and distinctness of the granules contained in their substance. Many, too, in place of remaining uniformly granular, begin to show a tendency to the formation of one or more nuclear spaces or vacuoles (Fig. 4), which appear as bright spots surrounded by more or less defined circles of granules. As the movements of the bioplasts diminish, this vacuolation increases in distinctness, and is very well marked when they have fairly ceased, which they do very gradually; changes in form persisting for some time after the cessation of free locomotion. As the movements cease, the majority of the cells also assume a more or less rounded form, a few only becoming fixed with irregular or lobed outlines, and contemporaneously they tend to accumulate in heaps and masses of varying extent (Fig. 4).

The preparation in this stage shows a multitude of irregular masses, composed of bodies which vary considerably in size, and which in refractiveness and general aspect closely resemble pus-cells in which the vital movements have ceased. The vacuoles are now very distinct and well defined, and the entire body has a denser, "plumper" appearance than it ever had before.

Whilst these phenomena have been taking place the serum remains quite clear and free of bacteria or monads, and the only change which occasionally occurs in it is a certain amount of staining, due to the escape of colouring matter from the corpuscles as the clot begins to soften. The preparation having reached this stage may remain unchanged for weeks, the serum continuing perfectly fluid and clear throughout, but in the majority of cases, the bioplasts pass on to further changes. The exact nature of these changes varies greatly in individual preparations and in the individual bioplasts of the same preparation. The bioplasts may gradually break up and disintegrate, filling the serum with molecular flakes, which for some time show indications of the outlines of the individual masses with more or less distinctness, but ultimately become uniform. Such flakes might very readily be described as flakes of monads, and be supposed to arise by aggregation, had the processes by which they are formed not been followed out. This may be regarded as the simplest method of termination of the bioplasts, but there are others which are more complex, and which, inasmuch as they give rise to very different appearances in individual specimens of blood, must be clearly distinguished and described. In many instances there appears to be a certain condensation of substance around the vacuole or vacuoles so as to leave a more fluid ring between this condensed portion and the outer margin of the bioplasts, which at the same time assumes more or less clearly the

appearance of a very delicate cell wall (Fig. 5). The granules contained within this fluid ring now take on an active swarming motion exactly resembling that observed in some common amœbæ occurring in specimens of water, and in the cells of many of the lower algæ. The movement persists for some time, and then, either ceases, leaving the bioplast apparently in the same condition in which it was previously, or the outer wall of the cell ruptures, and the swarming granules escape (Fig. 5). Once beyond the parent body and free in the fluid, they immediately become motionless, and have never been observed to move again. What the nature of these particles is, and to what their activity is due, remains uncertain, but they can, at all events, hardly be regarded as bacterial germs, seeing that their period of activity is confined to the period in which they are still contained within the parent bioplast.

The result of the escape of the granules is to convert the formerly uniform, granular, vacuolated bioplast into a body, consisting of a delicate cell-wall and a nuclear mass which does not nearly equal the cell-wall in circumference. This mass may remain more or less centrally situated, or, as more frequently occurs, it may pass to one or other side, and may then escape partially or even entirely from the cell-wall. The appearances naturally vary with the nature of the process which has taken place. In those cases in which the nuclear mass remains central, the entire body appears as a bright space bounded by a dark line, and containing a central molecular mass, while in those in which it goes to the side or escapes through the cell-wall, the bright space is left equally sharply defined from the surrounding fluid, but is either crescentic or quite empty and circular. Probably the most common appearance is that of a broad, bright, sharply defined crescent, the concavity being formed by the portion of the nuclear mass which is still included within the cell-wall, while the rest of it protrudes as a rounded mass exterior to it (Fig. 5), but empty spaces with free masses of granules condensed or scattered in various degrees are also abundantly present at this time. This escape or expulsion of the contents of the cell may take place without any previous formation of a nuclear mass and motile granules, but the result in any case is ultimately the same, and a series of bright, sharply defined, more or less empty, hyaline capsules remains.

This appearance varies with their situation: when free in the fluid they come out as pure white, flat spaces with fine dark outlines; whilst, when situated among the corpuscles, they are usually delicately shaded. The persistence of these capsules is wonderful, considering their extreme delicacy; and the surrounding fluid does not appear to enter them, or to cause them to collapse, although in some cases there appears to be open fissures in them. The nuclear masses gradually disintegrate after their exit, and are diffused through the fluid as flakes of molecular matter (Fig. 5).

Peculiar appearances are induced during the progress of the above changes in those cases in which masses of cells have been embedded in the interspaces of the clot, and in which the whole preparation has, as is sometimes the case, passed into

a syrupy condition. The outer walls of the cells appear to adhere to one another and to the margins of the interspaces, and the contents shrinking away and condensing appear as small circular masses in the centre of empty irregular vacuoles in the clot.

Subsequently to the escape of the contents of the cells, there is in many cases an abundant development of irregularly oval and rounded particles of various sizes throughout the preparation. They are of various forms, globular, irregularly lobed, and either scattered or arranged in pairs, trios or series (Fig. 6). Many of the series are very complex and much ramified, whilst others consist of linear series, each member of which is smaller than its predecessor. The nature of these bodies remains quite uncertain. Beyond a certain increase in size they have not been observed to undergo any further development, and in many cases they are probably of an oily nature. When of such a nature, they are from the first brightly refractive and perfectly structureless, and are ultimately, at the close of one or two months from the commencement of observation, resolved into oily flakes and strings, the latter of which might easily be mistaken for vibriones or fungal threads, more especially when they begin to break up into rows of separate oil globules.

In others, however, this does not appear to be the case, as they may in these instances be observed to become finely molecular, so that the preparation is ultimately crowded with minute molecular patches of various forms (Fig. 6). It is possible that the latter bodies may be the escaped, so-called "vacuoles" of the bioplasts. These are always surrounded with a portion of more or less condensed material, which would be likely to persist after the solution of the surrounding softer material.

As is frequently the case in preparations of blood kept under continuous observation in the same way as the above, milky spots, due to the appearance of small homogeneous circular bodies, may be observed in some numbers in the fluid, but they have not been seen to undergo any further development, and, as a rule, do not persist long.

After the appearance of the particles above described, the only further change noted has been a gradual disintegration of all the elements of the preparation; and, although the latter have frequently been kept for weeks under observation, no further development has taken place, and with very few and accidental exceptions, there has been no appearance of recognizable fungal, or bacterial elements in them.

It now remains to make a few remarks on the principal points of interest in connection with these observations. The conveniences afforded by a tropical climate for any such series of observations as these are very great, as the temperature as a rule is sufficiently high to secure that the activity of the bioplasts contained in the blood is not too rapidly checked. During a period of frequent observation in the course of the past season the thermometer ranged from a maximum of 98·2° F. to a minimum of 76·3° F.

It is not devoid of interest to remark that the use of immersion objectives involves a disadvantageous depression of temperature, due to evaporation of the film of water, which is placed between the lens and the covering-glass. The prolonged use of such a lens has frequently appeared in this way to check the activity of the bioplasts in the blood.

One of the most important points determined by these observations is the fact, that the blood in cholera is, as an almost invariable rule, free from bacteria, either actual or potential. This is the case as well shortly after death as during life, and holds in regard to every stage of the disease. In one or two cases, a slight development of distinct bacteria has occurred during the course of observation, but this is no more than may occur in the most healthy specimens of blood, and the idea that bacteria are normally present in the blood in cholera may be finally dismissed. It is not improbable that certain of the appearances observed in series of observations, such as those described above, may afford a clue to the origin of such an idea. At an early stage when the bioplasts are of great fluidity and tenuity, monad-like granules, contained in and moving with them, may be supposed to be free and endowed with independent motion, but this will be found, on prolonged observation, not to be the case, and as the density of the bioplasts increases the true relations of the granules will appear. At a much later stage, namely, at that of escape of the contents of the cells, patches of molecular matter and scattered granules may result; and finally, when general disintegration of the bioplasts occurs, large sheets and masses of evenly molecular matter may occupy much of the preparation, but these granules, micrococcoid patches and molecular flakes, are no new developments, but are clearly traceable to mere disintegrative changes in bodies previously present.

The molecular matter so produced, be it scattered or aggregated, undergoes no further development, and shows no motion or any other indication of vitality. The term bacteria is often very vaguely and loosely employed, but it is, under no pretext, applicable to mere dead particles due to simple disintegration.

As regards bacteria, so it is in regard to the presence of fungal elements as a normal and constant characteristic of the blood in cholera. There is absolutely nothing in favour of any such view; there is absolutely no evidence of the existence of fungal elements in the blood whilst in the body, and only very rare and clearly accidental development of such bodies after its removal from it. These questions, however, will be more fully referred to in a succeeding section (page 78).

Possibly the most important result to be derived from observations on the blood in cholera, conducted in the manner described above, is the explanation which they are capable of affording of the nature of the bioplastic bodies and cells so abundant in, and so characteristic of, evacuations passed during the course of the disease. We have previously pointed out that such evacuations frequently contain evidences of the escape of blood into the intestines, either by the presence of red corpuscles in greater or less abundance, and occasionally included within the

characteristic cells of the discharges, or by that of a more or less pronounced pinkish and sanguineous tinge of the fluids, with the subsequent appearance of blood crystals in them. Now if, as observation has proved, the bioplasts contained in the blood are capable of such activity and multiplication when removed from the body, and with quite abnormal surroundings, it is surely fair to allow them an equal, if not superior, capacity when exuded on the interior surface of the intestines.

Such bioplasts, in passing through the various changes described above, will come to present every modification of appearance and characters presented by those found in the discharges. In their earlier stages they will correspond with the freely motile amœbæ of the evacuations; when rather older they lose their freedom of motion and show mere feeble changes of form, ultimately becoming motionless and pus-like or rather exudation-like cells, such as are observed in the flakes of lymph in peritonitic and similar effusions, and such cells we know to form the great bulk of those present in perfectly recent choleraic dejections.

Whilst in this condition it has been already mentioned that they frequently show one or more distinct nuclear vacuoles in their interior, and they are then identical in aspect with the large mother-cells containing bioplast-masses, previously described in connection with the subject of the evacuations.

There is one class of bodies in the evacuations, the nature of which has hitherto been peculiarly puzzling and obscure, namely, that of flattened, whitish or pale-yellowish hyaline cells showing no evident structure or contents, but the observations on the changes occurring in the bioplasts of the blood explain the nature of these also, for the empty capsules persisting after the escape of the molecular contents of the pus-like cells, are exactly similar to the hyaline bodies of the evacuations, and unless the actual steps in their formation had been followed, their nature would have been as obscure as that of the latter cells has till now remained. Hyaline vesicles, somewhat resembling these, are, more or less, generally found in all intestinal discharges, and are probably the result of endosmotic processes acting on the epithelial cells, as was long ago pointed out by Heidenhain and Brücke in connection with appearances observed in healthy epithelium; they may occasionally be seen closely attached to the cells in those very exceptional cases in which epithelium can be detected in choleraic discharges, as well as very frequently in connection with the loose epithelium found in the intestines after death, as figured and described in the last report.*

These observations on the blood, especially when taken in connection with the light which they throw on the nature of the cells and bioplasts of the evacuations, do not tend to indicate the presence of a microscopically demonstrable morbid poison in either medium, they merely show that the escape of materials from the blood is sufficient to account for the presence of the most remarkable and constant microscopic features in the evacuations.

* Seventh Annual Report of the Sanitary Commissioner with the Government of India: Appendix B, Plate III.

B.—Results of microscopic examinations of the blood in health and in diseases other than cholera.

As might be supposed, these systematic observations on the blood in cholera were not commenced without our having, as we thought, made ourselves practically conversant with all the changes discernible in normal blood; indeed, on referring to our notes, we find that daily, and in several cases hourly, observations had been entered relative to about three dozen specimens examined in precisely the same manner as the foregoing, but in none of them is there any allusion to the phenomena just described. Whereas in the written description of the second case of the cholera-blood series, we find it entered on the fourth day that "the serous portion of the specimen is crowded with granular, white corpuscles, extremely like pus-cells." Then follow careful notes of between sixty and seventy specimens in which the various stages above summarised are minutely described.

Thinking that it might by no means be impossible that similar changes might have been overlooked in the normal blood series, we determined to go over this ground again, and found this to have been the case, to a certain extent at all events, in some samples of blood. Still even in these exceptional cases the difference is so marked that we almost venture to state that, given two samples of blood, one being choleraic and the other healthy, although to the naked eye, or at first sight under the microscope, no difference might be discerned, we could pretty accurately state on the second day to which of the two sources the specimens should be referred.

Similar amœboid corpuscles may very readily be detected creeping out of the blood clot in this climate without any special artificial arrangements being adopted to raise the temperature even in healthy blood; but in no single case have we hitherto seen them appear in anything like the same proportion as in the blood obtained from patients suffering from cholera, where not infrequently little white spots about the size of a millet-seed may be seen with the naked eye, which, when placed under the microscope, will be found to correspond with aggregations of these pus-like corpuscles. Added to this the corpuscles appear to be smaller and to disintegrate much more readily in normal blood; so much so that in the course of about twenty-four hours nothing special is to be observed, merely the usual proportion of white cells, with possibly some aggregations of molecules and a few hyaline cells, regarding the origin of which no conjecture could have been arrived at, had the earlier changes undergone by the preparation not been carefully watched; whereas in cholera these amœboid bodies, after they have become spherical, may, as has already been intimated, persist for several days without any marked change.

Whether this persistency be owing to the increased density of the blood in cholera, or to the character of the bodies referred to, we are not in a position to state; nor would we for a moment wish it to be inferred that any specific character can be attributed

to them, but it is evident that the blood in cholera is particularly adapted to their development, or at any rate to their being readily recognized and well preserved.

We have examined the blood in other diseases, and in such exceptional diseases as tetanus, but have failed to discover any such marked deviation from the normal standard in any single instance. Whilst examining some wax-cell preparations of the blood in a case of typhoid fever (the patient having been for two days delirious), we were particularly struck with the marked diminution in the number of white corpuscles, which, in the course of a few hours, are usually seen in the ring of serum surrounding the clot in normal blood; and also by the constant presence of numerous interlacing vibrio or bacteria-like filaments along the edge of the preparation, stretching across from one cluster of red corpuscles to another. No movements whatever were exhibited by these bodies, which, in the course of a few hours, became slightly beaded, and eventually disappeared.

So closely did they resemble the low forms of life above referred to, that we were at first much puzzled as to their real nature; but on subjecting a perfectly fresh sample of the blood to the fumes of osmic acid in the usual way, we found that under these circumstances no trace of the existence of the delicate bodies referred to could be detected. We therefore inferred that their presence in specimens otherwise prepared was due to the separation of fibrine, which had not had time to take place to any great extent before the fluid was fixed by the osmic acid.

The resemblance which these appearances bore to the description of the motionless *bacteridia* of Davaine, as occurring in the blood in "mal de rate" or malignant pustule, was very great; and we are strongly of opinion that the *bacteridia* so prominently set forth in connection with this malady, are not living organisms at all, but simply coagulated fibrine-filaments.

Whilst this report was passing through the press, Dr. Bastian's very remarkable work * came into our hands, and we were much impressed by a reference made in it to the experiments of M. Onimus, which show that "neither leucocytes nor any other kind of anatomical elements" are produced in serum whose fibrine has been coagulated.

This possibly accounts for the remarkable paucity in the number of white blood-corpuscles in typhoid fever when examined as above described, and appears to us to verify to a great extent the opinion which we have formed as to the nature of the bacteroid bodies in the blood in typhoid fever, and of the *bacteridia* in "mal de rate." Possibly, also, the great number of the bioplasts which appear in the serum of the blood in cholera, may be due to a diminution in the normal coagulability of the blood.†

The "pus-cells" described as occurring in the vessels in pyæmia, may be due to

* "The Beginnings of Life," 2 volumes: Macmillan and Co., 1872.

† This conjecture appears to receive a certain amount of corroboration from the fact that in two slight cases of cholera the blood was observed to contain such fibrinoid filaments coincidently with an unusually small number of leucocytes.

aggregation of bioplasts. It has long been known that in pyæmia the smaller vessels and capillaries, especially near the parts affected, are frequently blocked up with what are believed by many to be aggregations of pus-cells in various stages of disintegration; but another school, with Virchow as one of its principal expounders denies that these plugs are due to pus, but ascribes them to solid particles brought by the veins from the diseased tissue. Perhaps when the tendency in certain conditions of the blood to aggegration of particles of its plasma, in the manner described as occurring in cholera, becomes generally known, these views relative to the pus-like corpuscles in the small vessels may become materially modified. We have not as yet been able to obtain samples from blood from a patient suffering from pyæmia, but we may state that the nearest approach to the above described appearance of the blood in cholera was obtained in specimens of blood (examined by precisely the same method) from dogs, in whom a condition more or less approaching to pyæmia had been artificially produced.

It is neither impossible, nor without some show of reason to infer, that the same tendency on the part of these plasma particles to leave the clot, and to become separated from the red cells, may exist in the living tissues; that a tendency to accumulation in the minute vessels and capillaries may occur in cholera; and that this, to some extent at least, may be the cause of the extreme difficulty with which the capillary circulation is evidently carried on in the course of this disease.

These suggestions we make with much diffidence, as we have not yet been able to test their accuracy by direct experiment. In such complicated investigations it is often extremely difficult to adduce positive proof of the truth of inferences which are yet so far founded on evidence that they deserve notice.

The points in question will be made the subject of careful inquiry, but meantime it appears desirable that the possible accuracy of the views we have expressed should be recorded.

C.—Observations on the blood in connection with the question of monads and bacteria, of fungi and of sarcinæ.

Intimately associated with the zymotic theories of the production of disease, and notably of cholera, is the question of the existence of monads, bacteria and such-like organisms in the blood of the persons affected, either in such a condition as readily to be recognized, or in such an undeveloped state as to elude detection by the best objectives yet constructed. As to the former condition we have already very emphatically expressed the conclusion which our observations have forced upon us, at least so far as the blood in cholera is concerned, namely, that no such bodies can be seen in this fluid, either during life or within a few hours after death as an invariable concomitant of the disease.

Whether or not such organisms may, nevertheless, be potentially present, is a question to which we have devoted a considerable portion of our time. In order

to satisfy ourselves on this point, cursory examinations merely of any number of specimens of blood would have availed but little, consequently the plan already described for the *continuous* observation of preparations of this nature was adopted. Before starting, however, we satisfied ourselves that the amount of air present in the wax-cells resorted to was amply sufficient by inoculating samples of healthy blood with minute quantities of bacteria; and observing whether or not the latter could be seen to multiply as rapidly in these closed cells as in similar cells whose walls had been perforated in two or three places, so as to permit of the free ingress and egress of air, not the slightest difference could be observed. Fungi were also tested in the same way with identical results. Indeed, after the first few hours of observation, many of the preparations here referred to were thus ventilated, but this appeared to have no effect, save to render them more liable to invasion by fungi and acari.

We have preserved notes of one hundred and twenty-eight specimens of blood derived from various sources, each of which has been kept under observation for periods varying from three days to nearly three months. As, however, these would occupy so much space were they published in detail, we have tabulated the results in as simple a manner as we possibly could.

It will be seen from the following table that the number of instances in which monads or bacteria appeared in the specimens of blood, whether in health or in cholera, before or after death, is very insignificant; indeed, in not a single instance is it recorded that any such organisms were present when examined immediately after it was obtained. It may be remarked that no extraordinary precautions were adopted, such as exposing the covering-glass or the needle to the flame of a spirit-lamp—very ordinary precautions indeed having sufficed to prevent contamination to any great extent with any low forms of life whatever. Of the 22 specimens of healthy blood examined, distinct evidence of monads or bacteria was only once observed, and fungal filaments only appeared on three occasions, or at the rate of about 13 per cent. In the blood of cholera patients obtained during life, monads or bacteria were only observed on two occasions in 39 specimens, and fungi were seen to develop in six preparations, just 2 per cent. more than in healthy blood. Except on one occasion, the fungus was observed to have entered the preparation from without, the filaments having insinuated themselves between the covering-glass and the ring of wax at a spot where apposition had not been perfectly effected; in the exceptional case the filament emerged from the clot, and was probably derived from a spore deposited on the covering-glass by the duster.

The absence of these low forms of life is equally conspicuous in the table of the cholera-blood preparations obtained after death. In the greater part of the specimens so obtained, a series had already been under examination during life. Of the 18 cases recorded, there was not a single preparation which manifested distinct evidence of bacteria, either on the first or succeeding days, and fungi developed on four occasions only.

Tables showing the frequency with which Monads or Bacteria, Fungi, and Sarcinæ appeared during continuous observations of 22 *specimens of healthy human blood, and of* 57 *specimens of blood from cholera patients,* 18 *of which were obtained after death.*

PREPARATIONS OF HEALTHY HUMAN BLOOD.								
		MONADS OR BACTERIA PRESENT.*			FUNGI PRESENT.**			SARCINÆ PRESENT.
Series No.	Preparation No.	At first.	Within 6 hours.	Within 24 hours.	At first.	Within 24 hours.	Within a week.	Within a fortnight.
1	1	No	No	No	No	No	No	No
...	2	,,	,,	,,	,,	,,	,,	,,
...	3	,,	,,	,,	,,	,,	,,	,,
2	1	,,	,,	,,	,,	,,	Yes	,,
...	2	,,	,,	,,	,,	,,	Yes	,,
3	1	,,	,,	,,	,,	,,	No	,,
4	1	,,	Yes	Yes	,,	,,	,,	,,
5	1	,,	No	No	,,	,,	,,	,,
6	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	,,	,,
...	3	,,	,,	,,	,,	,,	,,	,,
...	4	,,	,,	,,	,,	,,	,,	,,
7	1	,,	,,	,,	,,	,,	,,	,,
8	1	,,	,,	,,	,,	,,	,,	,,
9	1	,,	,,	,,	,,	,,	Yes	,,
10	1	,,	,,	,,	,,	,,	No	,,
11	1	,,	,,	,,	,,	,,	,,	,,
12	1	,,	,,	,,	,,	,,	,,	,,
13	1	,,	,,	,,	,,	,,	,,	,,
14	1	,,	,,	,,	,,	,,	,,	,,
15	1	,,	,,	,,	,,	,,	,,	,,
16	1	,,	,,	,,	,,	,,	,,	,,
Total	22	...	1	1	...	...	3	...

PREPARATIONS OF BLOOD IN CHOLERA DURING LIFE.								
		MONADS OR BACTERIA PRESENT.*			FUNGI PRESENT.**			SARCINÆ PRESENT.
Series No.	Preparation No.	At first.	Within 6 hours.	Within 24 hours.	At first.	Within 24 hours.	Within a week.	Within a fortnight.
17	1	No	No	No	No	No	No	No
...	2	,,	,,	,,	,,	,,	,,	,,
...	3	,,	,,	,,	,,	,,	,,	,,
...	4	,,	,,	,,	,,	,,	,,	,,
18	1	,,	,,	,,	,,	,,	Yes†	,,
...	2	,,	,,	,,	,,	,,	No	,,
...	3	,,	,,	,,	,,	,,	,,	,,
...	4	,,	,,	,,	,,	,,	,,	,,
...	5	,,	,,	,,	,,	,,	,,	,,
...	6	,,	,,	,,	,,	,,	,,	,,
19	1	,,	,,	,,	,,	,,	Yes	,,
20	1	,,	,,	,,	,,	,,	No	,,
...	2	,,	,,	,,	,,	,,	,,	,,
...	3	,,	,,	Yes	,,	,,	Yes	,,
21	1	,,	,,	No	,,	,,	No	,,
...	2	,,	,,	,,	,,	,,	,,	,,
...	3	,,	,,	,,	,,	,,	,,	,,
...	4	,,	,,	,,	,,	,,	Yes	,,
22	1	,,	,,	,,	,,	,,	No	Yes††
...	2	,,	,,	,,	,,	,,	,,	Yes††
...	3	,,	,,	,,	,,	,,	,,	No
...	4	,,	,,	,,	,,	,,	,,	,,
...	5	,,	,,	,,	,,	,,	,,	,,
...	6	,,	,,	,,	,,	,,	,,	,,
23	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	,,	Yes
24	1	,,	,,	,,	,,	,,	,,	No
...	2	,,	,,	,,	,,	,,	,,	,,
25	1	,,	,,	,,	,,	,,	,,	,,
26	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	,,	,,
27	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	Yes	,,
28	1	,,	,,	,,	,,	,,	No	,,
29	1	,,	Yes	Yes	,,	,,	Yes	,,
30	1	,,	No	No	,,	,,	No	,,
31	1	,,	,,	,,	,,	,,	,,	,,
32	1	,,	,,	,,	,,	,,	,,	,,
33	1	,,	,,	,,	,,	,,	,,	,,
Total	39	...	1	2	...	...	6	3

PREPARATIONS OF BLOOD IN CHOLERA AFTER DEATH.								
		MONADS OR BACTERIA PRESENT.*			FUNGI PRESENT.**			SARCINÆ PRESENT.
Series No.	Preparation No.	At first.	Within 6 hours.	Within 24 hours.	At first.	Within 24 hours.	Within a week.	Within a fortnight.
34	1	No	No	No	No	No	No	No
35	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	,,	,,
36	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	Yes	,,
...	3	,,	,,	,,	,,	,,	No	,,
37	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	Yes‡	,,
...	3	,,	,,	,,	,,	,,	No	,,
38	1	,,	,,	,,	,,	,,	,,	,,
...	2	,,	,,	,,	,,	,,	Yes	,,
39	1	,,	,,	,,	,,	,,	No	,,
...	2	,,	,,	,,	,,	,,	,,	,,
...	3	,,	,,	,,	,,	,,	,,	,,
40	1	,,	,,	,,	,,	,,	Yes‡‡	,,
...	2	,,	,,	,,	,,	,,	No	,,
...	3	,,	,,	,,	,,	,,	,,	,,
...	4	,,	,,	,,	,,	,,	,,	,,
Total	18	...	...	...	...	...	4	...

* Under this heading in this and succeeding Tables only such molecules or staves are included as showed distinct evidence of vitality by form, growth, or movement.

** These, unless otherwise mentioned, refer to instances in which the fungal filaments manifestly invaded the preparation from without.

† The fungus seen to start from the centre of the clot.

†† The blood in these preparations had been mixed with a solution of acetate of potash and had been left unsealed.

‡ Penicillium.

‡‡ Penicillium and aspergillus heads were *distinctly seen* to be borne on branches arising from one and the same filament.

As to the presence of sarcinæ in the blood, which latterly have been alluded to (by Lostorfer and other observers) as being constantly present in this fluid, we can merely state that on two occasions only did we observe them make their appearance

during our examinations of the preparation of blood here referred to; and it so happens that whereas six samples of the particular blood alluded to were under observation, only in the two specimens, to which a solution of acetate of potash had been added, did the sarcinæ appear. We have recorded another case as being of a questionable nature, the bodies observed having appeared to us to be more like crystals which had assumed a sarcinoid arrangement: indeed, from what we have observed of sarcinæ under other circumstances also, we incline strongly to the opinion that they are crystalline rather than organised bodies.

Having in our own minds become perfectly satisfied that none of the organisms above alluded to existed in the blood in a state of health, or in cholera, and having also observed that when ordinary blood was inoculated with monads or bacteria, their multiplication and activity usually ceased in the course of two or three days, unless fresh material were added, we were still anxious to ascertain whether they would increase in a more marked degree, and whether their period of activity would be prolonged by being introduced into the circulation. With the view of attempting to clear up this matter, decomposing solutions swarming with monads, bacteria and vibriones were injected into the veins of dogs, a sample of the blood being in most instances previously examined for the sake of comparison, and the animals slaughtered at periods varying from a few minutes to a week after the operations. Our note book contains a record of forty-nine such experiments which we thus briefly epitomise:—

It will be seen from the table on page 79 that the minute organisms, with which decomposing organic solutions swarm, do not multiply on being introduced into the blood of healthy or diseased animals; for it must be borne in mind that the blood of several of the dogs experimented upon had, on a previous occasion, or even on two occasions, been contaminated in a similar manner, and could consequently scarcely be designated healthy.

Indeed, not only is it shown that the organisms under consideration cease to multiply under such circumstances as these, but that they actually diminish in number every hour they remain in the system, and eventually disappear altogether.

Out of twelve preparations of blood obtained from animals within six hours after the introduction of putrefying matter into their veins, active monads and bacteria were present in seven of them, or at the rate of about 58 per cent.; and out of thirty preparations examined, under similar circumstances within twenty-four hours, they were distinctly recognized in fourteen, or something under 47 per cent.; whereas, in nineteen specimens of blood derived from animals that had been inoculated in this manner from two to seven days previously, these bodies could only be detected in two of them, or only at the rate of about 10½ per cent., just 6 per cent. higher than was observed to be the case in healthy blood, which we have attributed to accidental circumstances.

It may be noted that in four of the dogs whose blood had been infected on two occcasions each, the blood, when examined within four, five and six days of the first infection, did not present a trace of these organisms.

Table showing the result of experiments to ascertain how long after the introduction of putrefying matter into the blood, bacteria, etc., could be detected.

Series No.	Preparation No.	Period expired since: The last operation.	Period expired since: A former operation.	Monads or bacteria present: At first.	Monads or bacteria present: Within 6 hours.	Monads or bacteria present: Within 24 hours.	Fungi present: At first.	Fungi present: Within 24 hours.	Fungi present: Within a week.	Sarcinæ present: At first.	Sarcinæ present: Within 24 hours.	Sarcinæ present: Within a fortnight.
1	1	2 minutes ...	...	No	No	Yes	No	No	No	No	No	No
...	2	,, ,, ...	...	Yes	Yes	,,	,,	,,	,,	,,	,,	,,
2	1	15 ,, ...	...	No	,,	,,	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	No	,,	,,	,,	,,	,,	,,	,,
...	3	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	4	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
3	1	2 hours ...	...	,,	,,	No	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	Yes	Yes	,,	,,	,,	,,	,,	,,
...	3	,, ,, ...	...	,,	No	No	,,	,,	,,	,,	,,	,,
...	4	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
4	1*	6 ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	2*	,, ,, ...	...	,,	,,	,,	,,	,,	Yes	,,	,,	,,
5	1*	7 ,, ...	...	,,	,,	,,	,,	,,	No	,,	,,	,,
6	1	8 ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
7	1	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
8	1	9½ ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
9	1	11 ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
10	1	14 ,, ...	...	,,	Yes	Yes	,,	,,	,,	,,	,,	,,
11	1	15 ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
12	1*	,, ,, ...	...	Yes	,,	,,	,,	,,	,,	,,	,,	,,
13	1	20 ,, ...	...	No	No	No	,,	,,	,,	,,	,,	,,
14	1*	23 ,, ...	...	Yes	Yes	Yes	,,	,,	,,	,,	,,	,,
15	1	24 ,, ...	3 and 5 days ...	No	No	No	,,	,,	Yes	,,	,,	,,
16	1	,, ,, ...	...	,,	,,	,,	,,	,,	No	,,	,,	,,
17	1	,, ,, ...	...	Yes	Yes	Yes	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	No	,,	,,	,,	,,	,,	,,	,,	,,
18	1*	,, ,, ...	...	,,	No	No	,,	,,	,,	,,	,,	,,
19	1	2 days ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	,,	,,	,,	,,	Yes	,,	,,	,,
...	3	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	4	,, ,, ...	...	,,	,,	,,	,,	,,	No	,,	,,	,,
20	1	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
21	1	,, ,, ...	4 days	,,	,,	,,	,,	,,	,,	,,	,,	,,
22	1	,, ,, ...	5 ,, ...	,,	,,	,,	,,	,,	,,	,,	,,	,,
23	1	,, ,, ...	6 ,, ...	,,	,,	,,	,,	,,	,,	,,	,,	,,
24	1	3 ,, ...	...	,,	,,	Yes	,,	,,	,,	,,	,,	,,
25	1*	,, ,, ...	...	,,	,,	No	,,	,,	,,	,,	,,	,,
26	1*	4 ,, ...	6 days	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	2*	,, ,, ...	,, ,, ...	,,	,,	,,	,,	,,	Yes	,,	,,	,,
27	1	,, ,, ...	...	,,	,,	,,	,,	,,	No	,,	,,	,,
...	2	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
...	3	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
28	1	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
29	1	,, ,, ...	...	,,	,,	,,	,,	,,	,,	,,	,,	,,
30	1	7 ,, ...	...	,,	,,	Yes	,,	,,	,,	,,	,,	,,
...	2	,, ,, ...	...	,,	,,	No	,,	,,	,,	,,	,,	,,
Total ...	49	...	...	4	10	16	...	...	5	...	...	...

* Preparations thus marked indicate that they were obtained after the death of the animal.

What becomes of them we are not in a position to state. Whether they become disintegrated or dissolved in the warm serum, or become merely filtered off during their passage through the tissues and glands, is a subject we hope satisfactorily to settle before long. In the meantime it may be remarked that we examined fluid expressed from the axillary and mesenteric glands in the greater number of the cases above tabulated (and in the same way), and have found that bacteria could be detected in them, especially in the mesenteric glands, at later periods than in the blood, but have noticed them absent, after a time, in these also.

As to whether these motile molecules, or staves, are themselves the cause of the disturbance which takes place in the system, consequent on the introduction of putrefying material into the blood (as will be fully referred to in a subsequent chapter), or whether they are merely the indicators that fluid containing them possesses this property, or indeed whether their presence at all is of any moment, we must for the present defer discussing. It will, however, be evident, on perusal of our notes of experiments on animals further on, that the question must have been constantly pressed upon our attention.

II. EXPERIMENTS ON THE INTRODUCTION OF ORGANIC FLUIDS INTO THE SYSTEM.

We had deferred taking up systematically that portion of the programme, drawn up for our guidance by the Army Sanitary Commission, relating to the experiments which should be carried out on lower animals in the conduct of this inquiry until the present year, as we did not feel that our knowledge of the various stages through which persons suffering from cholera have to pass, and of the *post-mortem* appearances associated with the disease, was sufficiently exact to enable us to conduct observations of this nature with profit.

It need scarcely be mentioned that every means was adopted to inflict as little pain as possible on the animals which have passed through our hands, considerably over a hundred dogs, together with several animals of a smaller kind.

Chloroform has invariably been resorted to: in no single instance has any animal been slaughtered except when thoroughly under its influence; and when, as in some of the experiments, considerable pain would have been inflicted by allowing the animal to recover from the effects of the anæsthetic before the experiment was concluded, it has been kept under its influence during the whole period of operation, two or three hours, as the case may have required.

At the commencement of these observations small animals were selected, such as rats, rabbits, or rather hares, for rabbits are not obtainable here; but we found the administration of chloroform so very frequently proved fatal with such animals, that they had to be abandoned. The same fatality was observed in connection with puppies and young dogs: indeed, even in dealing with large healthy dogs we calculate on losing about one in five through this cause alone. Moreover, the effects produced were of so contrary a character, even under precisely similar conditions, that we feel convinced that any data of this kind obtained by experiments on small and delicate animals are extremely liable to mislead.

This is a very unfortunate circumstance, not only because, as a rule, small animals are more easily obtained and more manageable, but also because the observations on

cholera-material hitherto recorded, and which have exercised great influence on the opinion of medical writers, and of the scientific world generally, have for the most part been derived from experiments on even more delicate animals than those above referred to.

This drawback will be evident to all who may carefully peruse some of the following cases, more especially those recorded in connection with the attempts to produce infection by the introduction of choleraic and other organic matters into the circulation.

The unsuitableness of small animals for experiments involving section of minute and deep-seated nerves arises, to a great extent at least, from a different cause, namely, the extreme tenuity of nerve fibres in such, which in man are large and easily accessible, and are even moderately large in well-developed dogs. Size is of still more importance, where, as in remarkable cases to be afterwards referred to, the section of a certain portion of a nerve appears to make such a vast difference in the result of the experiment.

We have, therefore, selected the dog not only from its size, but also from the fact of its food being very closely allied to that of man, as being more suitable to experiments of the nature here alluded to, especially as the organic substances hitherto experimented upon have not been introduced in the circulation through the digestive system. Had such a method been adopted, the tremendous powers of digestion of the native pariah or Bedouin dog would have rendered any comparative data unmistakably useless.* Added to this, the numbers obtainable and with tolerable ease (these dogs being under the ban of the Police here), it will be evident that, taking all things together, they are the most suitable animals for systematic investigation of this nature.

A.—Experiments on the injection of choleraic and other organic fluids into the veins of animals.

In order to judge of the validity of generalizations derived from any such series of experiments as that included under the above heading, it is clearly necessary that the precise grounds for these should be known. We shall therefore, in the first place, proceed to give a brief abstract of the results of various cases, condensed from notes taken at the time, and shall then proceed to draw any conclusions from them which the data appear in our estimation to warrant.

We are the rather inclined to such a course, seeing that almost any series of

* We purpose, however, availing ourselves of an early opportunity of trying the effect of injecting various substances directly into the small intestines of animals, by taking out a loop of the gut, and introducing the selected substance by means of a finely pointed syringe; thus overcoming this source of fallacy, at least as far as the direct action of the stomach is concerned.

careful experiments on animals has not merely a direct bearing on the point immediately at issue, but ought at the same time to be capable of throwing numerous sidelights on other subjects of physiological and pathological interest.

In proceeding to give a detailed account of the result of individual experiments, some more or less systematic arrangement of them is essential. The experiments in question, in this instance, might be classified on various principles; but an arrangement having as its basis the fact of the purity or dilution of the medium employed, and sub-divided according to the age of the material, in other words according to the amount of decomposition which it has undergone, appears to be as natural and as convenient as any. Such an arrangement has accordingly been adopted in regard to the experiments of which we now proceed to give an account.

1.—Experiments on the injection of pure choleraic fluids into the veins of animals.

(*a*) *The choleraic material used being fresh.*

Experiment I.—A large healthy pariah dog was put under chloroform, and nearly an ounce of choleraic evacuation was injected into the right femoral vein. The material injected consisted, in greater part, of grey watery fluid, but contained in addition numerous minute fragments of the flocculi characteristic of choleraic evacuations. The operation was performed at 8 A.M.

The animal continued dull and sluggish throughout the course of the day, but did not show the slightest indication of pain. It neither was purged nor vomited, and on the following morning, 24 hours after the operation, it appeared to be much livelier than on the previous evening. The wound in the thigh, however, presented an unhealthy aspect, and there was a considerable amount of swelling around it. The animal became rapidly more depressed and dull during the day, and in the evening appeared to be in a dying condition; but throughout it showed not a single symptom which could be supposed to resemble those of cholera.

As it appeared probable that it would die during the night, and that the results of *post-mortem* examination would therefore be vitiated, it was anew put under chloroform at 5 P.M., 33 hours after the injection, and the administration continued until respiration ceased. An immediate *post-mortem* examination was then performed, the results of which were as follows:—

There was much erysipelatous inflammation of an unhealthy nature around the wound extending for some distance up the flank. On opening the abdomen, the peritoneal cavity was found to contain no fluid, and the peritoneum both in its visceral and parietal layers appeared to be perfectly healthy. The intestines were empty, and in every respect appeared to be perfectly healthy. The liver was extremely fatty, and so soft and friable as to break under the slightest pressure. On its upper surface there was a radiating cicatrix which, from its appearance, seemed to indicate the site of an

old rupture of the organ. The larger veins contained fluid blood, and there was no indication of the occurrence of embolism in any part of it. The kidneys were extremely fatty, and the left one contained one or two embolic masses of considerable size, projecting on the surface and extending deeply into its substance. The bladder was full of urine. The pleuræ, lungs and heart were perfectly normal in aspect. The blood showed no traces of bacteria in it when carefully examined a quarter of an hour after its removal from the heart.

(*b*) *The choleraic material used being* ONE *day old.*

EXPERIMENT II.—A dog which had been previously the subject of injections of choleraic media, both femorals and one basilic vein having been previously tied (*vide* Experiments VI, XXXVI and XL), but which was nevertheless in very fair condition, was put under chloroform at 7-30 A.M. The remaining basilic vein was now opened, and four drachms of a choleraic evacuation passed by a patient in hospital 24 hours previously, and which had remained in a bottle during the interval, were injected into it.

The animal rapidly recovered from the effects of the chloroform, and, saving that it limped slightly in walking, appeared to be in no way affected by the operation. It continued apparently in health throughout the day, walking about and feeding, and on the following morning also it showed no symptoms of illness. It was therefore killed under chloroform as in the previous experiment, and an immediate *post-mortem* examination performed.

There was a localised sac of pus in the sheath of the vessel last injected. The pus appeared to be perfectly normal, and there was little inflammation around the sac. The wounds caused by the previous operations were clean and healthy, that in connection with the femoral vein of the opposite side being almost entirely healed up. The abdominal and thoracic organs were carefully examined, but save for the existence of one or two minute, congested, possibly embolic patches in the liver, they appeared healthy and normal.

EXPERIMENT III.—A healthy young pariah dog was put under chloroform at 7 A.M., and four drachms of choleraic evacuation, which had stood for 24 hours in a bottle, were injected into the right femoral vein. The operation was performed on the same morning and with the same material as Experiment II.

The animal once or twice ceased to respire during the operation, but, by resorting to artificial respiration, sensibility was restored, and it eventually recovered from the influence of the chloroform.

Several days of illness supervened, during which the animal appeared hardly able to walk, became much emaciated, and was affected with slight convulsive twitchings. These symptoms gradually passed off, and at the close of a week after

the performance of the operation, it appeared to have entirely recovered. It was accordingly killed on the morning of the eighth day, and an immediate *post-mortem* examination made.

On opening the abdomen the peritoneal cavity was found to contain a considerable quantity of reddish serous fluid. The intestines were congested externally, and contained here and there patches of reddish mucus. The remaining abdominal and thoracic organs appeared to be perfectly healthy.

(*c*)—*The choleraic material used being* TWO *days old.*

EXPERIMENT IV.—A large, healthy young pariah dog was put under chloroform, and about half an ounce of choleraic material was injected into the right femoral vein. The material employed consisted of the supernatant fluid of an evacuation, which had stood for 40 hours, and which had, when quite recent, been chiefly characterised by the profusion of large, active amœboid bodies present in it.

The dog rapidly recovered from the influence of the chloroform, and appeared to be quite unaffected by the operation. On the following morning, 24 hours after the injection, there were no symptoms of illness, and during the subsequent three days the animal appeared to be in perfect health, so that, on the morning of the 4th day from the first operation, he was made the subject of another experiment (*vide* Exp. XXII).

EXPERIMENT V.—A very young and healthy pariah pup was put under chloroform, and two or three drachms of the supernatant fluid from a choleraic evacuation which had stood in the laboratory for 48 hours were injected into the right femoral vein.

The animal recovered rapidly and perfectly from the influence of the chloroform. It showed no symptoms of illness, and on the following day appeared to be quite well. As it continued in perfect health, it was subjected to a fresh operation 48 hours after the performance of the former one (*vide* Exp. XXXV).

EXPERIMENT VI.—A healthy pariah dog, into the right femoral vein of which choleraic material had been injected three days previously without result, was put under chloroform, and four drachms of a dejection, which had been passed 48 hours before by a patient who had been ill for 24 hours, were injected into the femoral vein of the opposite side.

The dog was never fully under the influence of the chloroform, and very soon appeared as though nothing had happened to it. On the following day it seemed to be quite well and remained so until after the lapse of three days, when it was again operated on (*vide* Experiment II).

(d)—The choleraic material used being THREE *days old.*

EXPERIMENT VII.—A strong healthy pariah dog was put under the influence of chloroform, and four drachms of choleraic fluid were injected into the left femoral vein. The fluid was derived from an evacuation which had been kept for 72 hours.* It was watery, and at the time of the operation had but a very slightly offensive odour and a faint alkaline re-action. There was hardly any sediment present, and the material injected consisted entirely of liquid crowded with very large and active, stiff-looking bacteria, together with myriads of active flagellated monads.

The animal appeared to be very little affected by the operation, showed no symptoms of disease throughout the day, and by the following morning seemed to be quite well. Chloroform was accordingly again administered, and continued until death occurred 24 hours subsequent to the performance of the injection.

A *post-mortem* examination was performed at once, the abdomen being opened before respiration and circulation had finally ceased. There were no signs of peritonitis present. The mucous surface of the intestines appeared to be quite healthy. Scrapings from it showed merely normal epithelial cells and villi with the usual sprinkling of minute bacteria. The mesenteric glands were congested and contained a good deal of fluid in their interior. A preparation of this fluid was mounted in a wax cell and examined one hour and a half afterwards. It was found to consist of a clear liquid, containing no recognisable bacteria or vibriones, but full of red blood-corpuscles and active amœboid bioplasts. It was again carefully examined 24 hours later, but the only change observable in it was that the bioplasts had all become motionless and circular. The rest of the abdomen and thoracic organs were apparently healthy.

Two preparations of blood from the heart were mounted as usual in wax cells. These were examined about an hour afterwards, and again after the lapse of 24 hours. On neither occasion did they show anything abnormal, the serum was perfectly clear and free from all trace of bacteria or vibriones, and an abundance of leucocytes crawled out of the clot and subsequently underwent their usual changes.

EXPERIMENT VIII.—Immediately after the injection of the previous experiment had been completed, another very large healthy pariah dog was put under the influence of chloroform, and six drachms of the same fluid were injected into the right femoral vein.

The animal rapidly recovered from the influence of the chloroform, and did not at first appear to be much affected by the operation, being able to walk to the kennel with apparent ease. It rapidly, however, became much depressed, and died within three hours. A *post-mortem* examination was performed five hours after death.

* The case from which it was derived was a very slight one, rather of choleraic diarrhœa than of cholera, and made a rapid recovery.

Post-mortem rigidity was strongly marked. On opening the abdomen there were found to be no signs of peritonitis. The small intestine was pale externally. On opening it, it was found to be coated with a thick soft substance of pink hue. This layer was quite loose, and easily removed from the subjacent mucous membrane, and was found to be composed of detached epithelium. When it was washed off, the denuded surface of the membrane became visible, from which only a very little material could be scraped, consisting of imperfectly developed epithelial cells, and containing an abundance of very long, uniseptate or jointless vibriones, lying motionless or progressing in a serpentine fashion over the field, as represented in the woodcut (Fig. 1).

For about six inches immediately above the ileo-cœcal valve the gut appeared quite healthy and unaffected, but everywhere else the epithelial coating of the mucous membrane appeared to be detached.

The mesenteric glands were soft, and not congested, but of a dirty yellow colour on

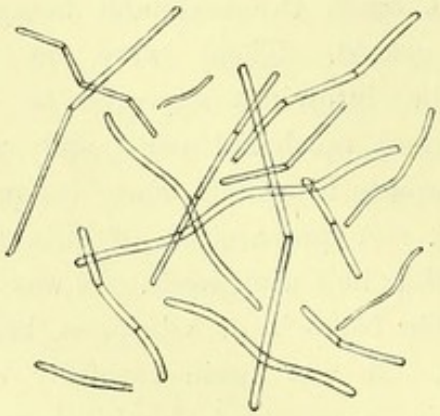


FIG. 1. × 500.
Oscillatoria-like vibriones obtained on the mucous surface of the small intestines and in the mesenteric glands.

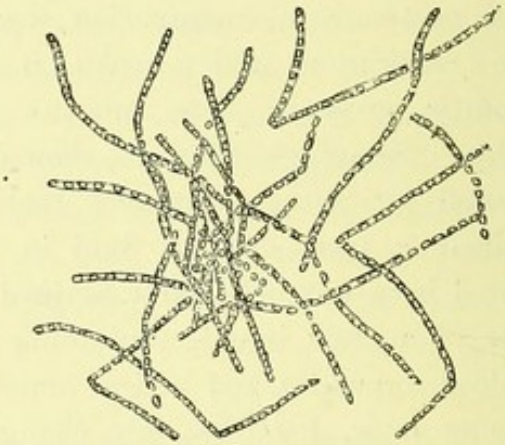


FIG. 2. × 500.
Appearances presented by the bodies in Fig. 1 on the third day.

section, and containing an abundance of fluid. A preparation of this fluid was mounted in a wax cell and carefully examined an hour and a half afterwards. It was found to contain an abundance of gland-cells, and to be swarming with elongated vibriones like those present in the intestines, for the most part uniseptate, and either still or only moving slightly. It was again examined sixteen hours subsequently, but no changes had taken place in the condition of the vibriones, although the majority of the gland-cells had broken down, and numerous clusters of fatty crystals had made their appearance.

The large intestine was normal in appearance, and the remaining abdominal organs were healthy. The stomach contained a little glairy fluid.

On opening the thorax there was found to be no pleurisy. The lungs were collapsed, the left one totally so, whilst the right was partially congested. The pericardium contained a little fluid, and there was slight congestion of both the visceral and parietal layers. The heart was healthy.

A preparation of blood from the right ventricle was mounted in a wax-cell and

examined an hour afterwards. At that time no bacteria could be detected in it, but crystals had begun to appear, and the serum was stained with the colouring matter of the red-corpuscles, whilst sixteen hours afterwards the whole of the preparation was converted into a mass of large blood-crystals.

EXPERIMENT IX.—On the completion of the preceding operation, Experiment VIII, another very large pariah dog was put under the influence of chloroform, and one ounce of the fluid employed in it was injected into the right femoral vein.

The animal at first appeared to be very little affected, and, like the dog of the preceding experiment, walked off to the kennel with ease and without manifesting any symptoms of pain or inconvenience. It died, however, within four hours, and a *post-mortem* examination was performed four hours after death.

Post-mortem rigidity was strongly marked. On opening the abdomen the small intestines were found to present precisely the same appearances, both externally and internally, as in the preceding case. There was the same separation of the epithelium, and the resulting formation of a soft, pink, creamy substance, and in this case also the portion of the gut immediately above the ileo-cœcal valve was apparently unaffected.

The only feature in which the intestines in this instance differed from the others consisted in there being a certain amount of watery fluid present in them. Towards the lower end of the ileum, just above the unaffected portion of the mucous membrane, the separation of the epithelium was not so far advanced as higher up, and appeared to be in a state of transition towards such a condition.

The mesenteric glands were highly congested internally, of a soft consistence, and contained an abundance of pink fluid. A preparation of this fluid was mounted as usual in a wax-cell. When examined an hour and a half subsequently, it was found to contain an abundance of minute bacteria, a sprinkling of the long vibriones occurring in the glands and intestines of the previous case, together with normal gland-cells and numerous red blood-corpuscles. Sixteen hours later, it contained an abundance of minute active bacteria, together with molecular matter, fatty crystals and cells, but showed none of the elongated vibriones previously present in it.

The large intestine and appendix vermiformis were normal in aspect, and the rest of the abdominal viscera appeared healthy. The bladder contained a little urine.

On opening the thorax there were found to be numerous large cancerous nodules throughout the substance of both lungs, which were collapsed, but contained a little air. There was slight inflammation of the parietal pericardium, and the visceral layer also was somewhat injected.

A preparation of blood was, as usual, procured from the right ventricle and mounted in a wax-cell. When examined about two hours afterwards, the serum was found to be deeply stained with the colouring matter of the red corpuscles, and to contain numerous minute active particles, but no distinct bacteria could be detected

in it. Sixteen hours afterwards it was crowded with large blood-crystals and contained an abundance of minute active bacteria.

EXPERIMENT X.—A small healthy pariah dog having been put under the influence of chloroform, about three drachms of the same fluid employed in the three preceding experiments, but which had now been kept for nearly eight hours longer, were injected into the right femoral vein. The injection was performed at 4 P.M., and the animal died during the night. A *post-mortem* examination was performed at 7 A.M. of the following day.

Post-mortem rigidity was well marked. There was a little reddish serum in the peritoneal cavity, but the intestines and mesentery were not congested. On laying open the small intestine, the interior was found to present the usual appearances, the portion immediately above the ileo-cœcal valve being unaffected, and the rest of it covered with a soft pink coating of detached epithelium.

Preparations of this pink material as well as of matter scraped from the subjacent denuded mucous coat were examined. The former were found to consist of cylindrical epithelial cells, and to contain numerous long serpentine vibriones similar to those found in the intestines and glands of the dogs of the previous experiments. The latter preparations consisted of imperfectly developed epithelial cells, with an even greater abundance of the elongated vibriones (Fig. 1), which ultimately resolved themselves into a network of leptothrix-filaments (Fig. 2).

The mesenteric glands contained pinkish fluid, a preparation of which was mounted in a wax-cell. When examined an hour afterwards, the gland-cells were found to be considerably disintegrated, whilst the fluid contained great numbers of the elongated serpentine vibriones, described in the previous preparations, in a state of full activity. The majority of them appeared to be uniseptate with a kind of hinge joint in the middle.

The rest of the abdominal organs were healthy.

There was a little reddish serum in the pericardium; the right side of the heart was full of fluid blood, and the left contained a little also.

A preparation of blood was as usual mounted in a wax-cell, which was examined an hour and a half afterwards, and found to contain numerous minute molecules in active motion, but no distinct bacteria. Twenty-four hours afterwards it was crowded with large needle-shaped blood-crystals, and the serum had almost dried up.

(*d*)—*The choleraic material used being* FOUR *days old.*

EXPERIMENT XI.—A small healthy pariah dog was put under the influence of chloroform, and four drachms of the fluid employed in Experiments VII, VIII, IX and X, but which had now been kept for 96 hours, was injected into the right femoral vein. The animal seemed to be very little affected by the operation, and

ran off to the kennel very cheerfully a few minutes after it was completed. It remained in apparent health, and was killed under chloroform about 9 hours subsequently.

During the administration of the chloroform, tarry liquid escaped from the rectum, and the large intestine was subsequently found to be full of similar material. The small intestine for nearly two feet above the ileo-cœcal valve appeared healthy, but above the mucous membrane was coated with a sanguineous layer, the epithelium however was not detached. The mesenteric glands were very much congested and full of reddish fluid. Some of them were reserved in a moist chamber for 14 hours. On sections being made at the close of that period, the gland was found to contain fluid in its interior swarming with active bacteria, and containing a sprinkling of long, active, serpentine vibriones similar to those found in the preceding experiments with the same fluid. A preparation of the fluid from the glands was also mounted in a wax-cell at the *post-mortem* examination. On examination a quarter of an hour afterwards, it was found to be full of red blood-corpuscles and crowded with minute motionless molecules. Twenty-four hours later many of these particles were in active motion, but there were no elongated vibriones present. The rest of the abdominal and thoracic viscera were healthy, and there were no traces of pericarditis.

Two preparations of blood, one from the vena portæ, the other from the right ventricle, were mounted in wax-cells as usual. They were examined a quarter of an hour afterwards; the latter contained numerous motionless molecules, the former a few small blood-crystals, but in neither were there any distinct bacteria. They were again examined after an interval of fourteen hours. At this time the preparation of portal blood contained numerous moving molecules, and an increased number of crystals, whilst the other preparation was apparently quite unchanged.

EXPERIMENT XII.—A young and healthy dog was put under chloroform, and four drachms of choleraic dejection, which had been passed ninety-six hours previously, injected into the right basilic vein.

The animal came rapidly out of the influence of the chloroform, but its respiration was disturbed, violent and gasping. Towards the evening of the same day it began to pass reddish, mucous evacuations, and it continued to do so until 5 A.M. of the following morning, when it died, 22 hours after the operation.

A *post-mortem* examination was performed at 7 A.M. On opening the abdomen, the cavity was found to be free from fluid and the peritoneum was smooth and shining, appearing in every respect to be perfectly healthy. The large intestine was throughout coated with a layer of thick, dark red mucus which ceased sharply close to the ileo-cœcal valve. The small intestines showed small patches of red mucus on the interior of the jejunum and ileum, whilst the duodenum appeared to be perfectly healthy.

The liver contained a few extravasated spots of small size, and one about the size of an almond beneath the peritoneum close to the gall-bladder. The spleen was pale and bloodless. The kidneys appeared to be perfectly healthy.

On opening the chest the pleural cavities were found free of fluid, and the membranes, like the peritoneum, appeared perfectly healthy. The left lung was universally mottled and congested. It was gorged with blood, and exhibited numerous small spots of extravasation probably due to embolism, both superficially and throughout its substance. The right lung showed numerous blackish spots towards the base, but it was not universally congested like the right one. The pericardium was healthy and contained no fluid. The surface of the heart, more especially of the left ventricle, was covered with yellowish-white miliary spots, and small points of extravasation. The cavities of the right side were extremely distended and full of soft, black clot.

The left ventricle contained a little fluid blood.

EXPERIMENT XIII.—A healthy pup was put under chloroform, and three drachms of choleraic material injected into the left femoral vein. The material consisted of the fluid and sediment of an evacuation thoroughly shaken up, and was in an active state of decomposition, the fluid being covered with a thick layer of bacteria, and the sediment consisting in greater part of amorphous matter with a few persistent red blood corpuscles. The injection was performed at 9 A.M., and the dog rapidly came out of the influence of the chloroform. It died at midnight of the same day without having shown any choleraic symptoms.

A *post-mortem* examination was performed at 8 A.M. of the following morning, 23 hours after the operation. The *post-mortem* rigidity was well marked. There was no evidence of inflammatory action around the wound in the thigh, which appeared clean and healthy. On opening the abdomen, the cavity was found to be free of fluid, the surface of the small intestines appeared slightly roughened, but the parietal peritoneum was perfectly smooth and glistening, and there was no evidence of inflammatory action present. The stomach was empty, and there were a few ecchymosed spots on the mucous membrane. The duodenum appeared healthy and contained a small quantity of bile-stained mucus. The mucous membrane was perfectly free of injection throughout the upper portion of the jejunum, but towards the lower extremity there was an ecchymosed patch three or four inches in length. The ileum contained an abundance of mucus of a peculiar reddish hue. The large intestine was also coated with abundant reddish mucus.

The liver both on the surface and throughout its substance showed numerous small, light coloured spots about the size of small shot. There were no inflammatory rings around them; after the specimen had been for twelve hours in a weak solution of spirits, these spots, where on the surface, appeared slightly prominent; but these prominences disappeared on exposure to the air, and slight depressions replaced them,

appearing to indicate that they had been due to an abnormal absorption of fluid at these points. On microscopic examination, the material composing these light coloured spots was found to consist of molecular matter and liver-cells in various stages of disintegration. This spleen was normal in appearance. The kidneys also appeared healthy.

On opening the chest the pleuræ were found to be healthy. The trachea and bronchi were empty and normal. The lungs were collapsed, containing very little air. They appeared to be injected on the surface, contained a little black blood, and presented a somewhat pneumonic aspect. The smaller bronchial tubes contained a yellowish frothy fluid. The pericardium was healthy. The right auricle was distended with coagulum, part of which was black, part gelatinous and yellowish. The right ventricle was in a similar condition. The pulmonary artery was full of a similar coagulum. The left auricle contained a little dark clot and the left ventricle was strongly contracted and empty. The pulmonary veins were full but not distended with blood.

EXPERIMENT XIV.—A small dog into both of whose femoral veins aqueous solutions of choleraic material had been previously injected without the slightest result (*vide* Experiments XXXIV and XXXVIII) was put under chloroform, and two drachms of the supernatant fluid of a dejection which had been kept for 96 hours were injected into the right basilic vein.

The material injected contained innumerable monads, bacteria and vibriones, together with a few amœboid bodies about the size of white corpuscles. The operation was performed at 7.30 A.M., and the dog quickly recovered from the influence of the chloroform, was able to support himself at once, and very shortly appeared as though nothing had happened to it. The animal continued in perfect health, eating and drinking freely, and having certainly improved in condition during the period in which he had been subjected to operations involving the ligature of both femoral and one of the basilic veins.

Three days subsequent to the last operation, a specimen of blood was taken for microscopic observation, and the dog was then let loose to return to his native wilds, and no doubt to regret the regular diet and attention which he received during his period of service to science. The blood was carefully examined but without yielding the slightest evidence of the presence of monads, bacteria or vibriones.

EXPERIMENT XV.—A large healthy young dog was put under chloroform, and about seven drachms of the supernatant fluid of an evacuation which had been kept for 96 hours injected into the right femoral vein. Five hours subsequent to the operation the dog died somewhat suddenly, having passed about a pint of liquid evacuation just before death.

A *post-mortem* examination was performed four hours after death. The body was

still warm, and there was no *rigor mortis*. On opening the abdomen, a little sanguineous fluid was found in the peritoneal cavity. The outer surface of the intestines was much congested and of a purple colour. The stomach was healthy. The mucous surface of the duodenum was normal. The jejunum contained reddish-yellow frothy fluid, becoming pink towards the lower extremity; but there were no erosions of the mucous membrane. Towards the middle of the ileum the contents were of a sanguineous aspect and of fluid consistence, but they became paler towards the lower extremity. In the lower half of the ileum there were patches of extreme congestion corresponding, as a rule, with patches of *tricocephalus dispar*. Towards the ileo-cœcal valve the intestine appeared to be healthy. The large intestine exhibited a few ecchymosed spots, but was otherwise healthy in appearance. The liver was fatty and showed small clots penetrating its substance. The gall-bladder contained bile. The kidneys were slightly congested, but otherwise normal. The bladder contained about three ounces of clear urine.

The pleural cavity contained a little slightly sanguineous fluid. The lungs were collapsed, containing very little air; but they were not congested. The pericardium contained about two ounces of fluid similar in appearance to that present in the peritoneal and pleural cavities. The right auricle and ventricle were full of dark coloured clot.

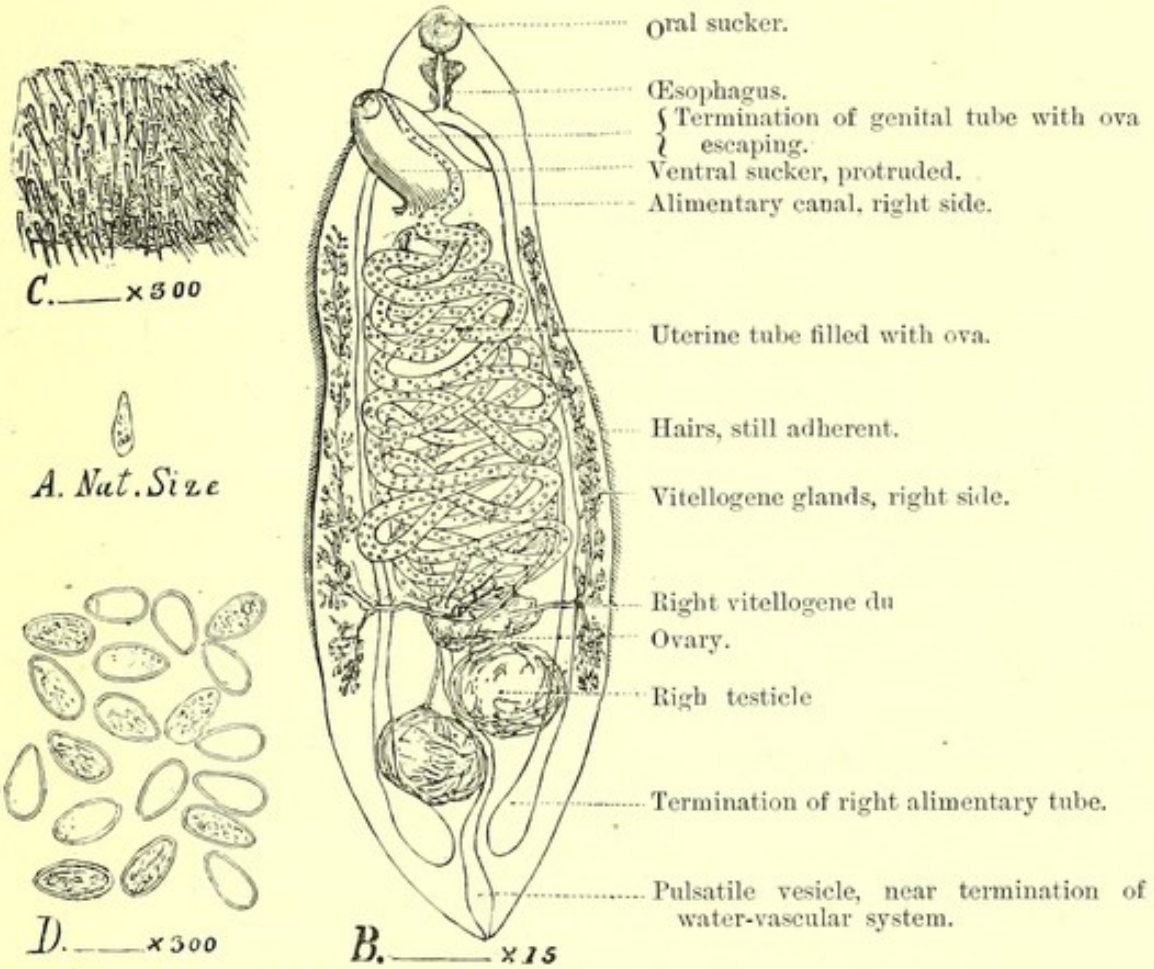
EXPERIMENT XVI.—A healthy pariah dog was put under the influence of chloroform at 7 A.M., and half an ounce of the supernatant fluid of a choleraic evacuation* which had been kept for four days was injected into the right brachial vein. The fluid injected was peculiarly fœtid, and was full of fine granular *débris* and bacteria. The animal rapidly recovered from the influence of the chloroform, but continued in a profoundly depressed condition until about 1 P.M., when he died. During the interval he neither vomited nor passed any stool.

A *post-mortem* examination was performed at 4-30 P.M. *Rigor mortis* was strongly marked. There was no fluid in the peritoneal cavity; but there was a certain amount of injection of the omentum and mesentery with a good deal of dark pigmentary deposit in the same localities. The intestines were very pale, externally almost white. Throughout the entire course of the small intestines, from the pylorus to the ileo-cœcal valve, the mucous membrane was congested, softened, and apparently partially disorganized. It was coated with a thick layer of semi-fluid mucous material; and on this being wiped off, the surface beneath presented a brush-like aspect due to the

* This dejection was passed by a patient in the General Hospital. He was a sailor who had been in the harbour for only three days, and who had, previous to his seizure, never been over the side of the ship. The symptoms came on with extreme violence and suddenness, whilst he was in full health. The evacuations were *extremely* characteristic, and the term "rice-water" was peculiarly adapted to describe their appearance. That examined was passed two hours after seizure. On microscopic examination, the flocculi were found to consist entirely of brightly refractive cells, resembling those found in recent exudations, embedded in shreds of fibrinous material (so perfect was the resemblance that slides consisting of the flocculi and slides of quite recent flocculent exudation, removed from the surface of the liver, associated with peritonitis, when placed under separate microscopes could not be distinguished the one from the other); these cells in the course of a few hours broke down completely, whereupon the extraordinary resemblance which this dejection bore to rice-water disappeared.

injection of the villi. The material was, in some parts, yellowish-white ; but in general was of various shades of pink and resembled strawberry-cream in appearance.

On microscopic examination, it was found to be composed almost entirely of cylindrical epithelium mixed with bacteria and amorphous particles. The large intestine also contained pinkish mucus, but the membrane was not injected save along the edges of the rugæ. The stomach contained semi-digested food, and was slightly congested. Towards its pyloric extremity there was a very hard fibroid tumour apparently of a schirrous nature. The liver appeared healthy ; there were numerous *distomata* in the bile ducts.* There were no traces of embolism throughout its substance. The gall-



* Fig. 3, DISTOMA FOUND IN THE BILE DUCTS OF DOGS.

A.—The parasite figured natural size.

B.—Ditto magnified 15 diameters.

C.—Minute hairs covering the entire body when fresh and before being manipulated, magnified 300 diameters.

D.—Ova squeezed out of the uterine tube, magnified 300 diameters.

This distoma is not infrequently met with in the bile ducts of dogs in this country. With the limited supply of literature on this subject within our reach, we have, however, not been able to refer it to any described species, and have therefore introduced a woodcut showing its size, form and minute anatomy, together with those of the ova. It appears to us to be very closely allied to the species discovered by Dr. Cobbold in the liver of the American red fox, and described and figured by him in his valuable work on Entozoa ; indeed if, on re-examination, it be found that that parasite has been, inadvertently, drawn by Dr. Cobbold as seen from the back—a mistake into which we ourselves fell, when the first specimen was sketched—this may turn out to be identical with the species described by this Author under the name of *Distoma Conjunctum*. We strongly suspect this to be the case.

bladder contained bile. The spleen and kidneys were healthy. On opening the thorax, the pleural cavities were found to be free of fluid, and the membranes appeared to be perfectly healthy. The lungs were collapsed, airless, and containing very little blood. The pericardium was slightly injected. The right cavities were distended with fluid blood, and the left side also contained a little blood.

Preparations of the blood were procured, and whether under common covering glasses, or in hermetically sealed wax-cells, were found to be swarming with very active bacteria after the lapse of twelve hours.

EXPERIMENT XVII.—A large healthy pariah dog was put under chloroform at 5 P.M. of the same day in which the preceding experiment was performed, and half an ounce of the same fluid employed in it injected into the right median vein. The operation was rapidly and successfully performed, and the animal quickly revived; but it appeared to be in a condition of profound collapse while under observation, and died during the course of the night, having passed some liquid mucous evacuations of a pink colour during the interval. The evacuations passed immediately after the operations were natural in colour and consistence.

A *post-mortem* examination was performed at 7 A.M., 14 hours after the injection took place. *Rigor mortis* was strongly marked. Pinkish fluid* ran from the nose and mouth when the body was lifted. There was no evidence of peritonitis, and the external surface of the intestines was very pale, as in the preceding case. The stomach contained a little pale pinkish mucus; but the membrane beneath was not congested. The duodenum contained more abundant and more highly coloured semi-fluid mucous matter, and the mucous membrane throughout the rest of the small intestines was softened, and coated with similar material. There were also small spots of extravasation throughout. The large intestine was not affected.

The mesenteric glands were all intensely congested and full of pinkish fluid closely resembling the intestinal material. The latter was found on microscopic examination to be composed of cylindrical epithelium mixed with abundance of bacteria and vibriones. The liver was variagated with light, yellowish fatty spots. It contained no evidences of embolism. The kidneys and spleen were perfectly healthy. The bladder was empty. The pleural cavities were healthy, and the lungs were collapsed, pale and devoid of any traces of embolism. The pericardium was quite healthy. The right cavities of the heart were empty, and the left contained a little fluid blood. Preparations of blood were procured from the heart and from one of the systemic veins. These, when examined a quarter of an hour subsequently, showed no active bacteria, but a uniform sprinkling of minute motionless particles throughout the

* The fluid consisted of mucus containing innumerable ova and a few perfect specimens male and female, of *Pentastoma tænioides*.

serum. Twenty-four hours subsequently the preparations were crowded with active bacteria.

EXPERIMENT XVIII.—This experiment was performed at the same time and with the same material as the preceding one. A large healthy dog having been put under the influence of chloroform, four drachms of the fluid were injected into the right brachial vein.

In consequence of a failure in the first attempt at injection and of the subsequent slipping of a ligature, the animal was both kept for some time under the chloroform, and moreover lost a considerable quantity of blood. The operation was at length, however, successfully performed. The dog seemed to be much depressed and whined as though in pain for some time.

During the night, however, he improved greatly and drank some water; and on the following morning he ate and drank greedily, and seemed to suffer more from stiffness of the wounded limb than from any constitutional symptoms. The wound looked clean and healthy, and the animal was bright and lively in appearance. He continued free from any constitutional symptoms, and five days after the operation was set at liberty in full health and excellent spirits.

EXPERIMENT XIX.—A pariah dog of average size put under the influence of chloroform at 7 A.M., and four drachms of the supernatant fluid of a choleraic evacuation which had been kept for 96 hours were injected into the right femoral vein. The dejection from which the material employed was derived was passed by a patient in the General Hospital whilst in profound collapse, and consisted almost entirely of watery fluid, only a very little flocculent sediment being present. These flocculi, when quite recent, showed mere flakes of minutely granular matter with a few hyaline cells and myriads of active infusoria. The material injected was entirely free from particles of sediment and consisted of an opalescent fluid swarming with active bacteria and containing a few molecular flakes and active ciliated infusoria. The operation was performed rapidly and with perfect success, and the dog quickly recovered from the influence of the chloroform. It passed a healthy evacuation soon after the close of the operation and showed no symptoms of pain, but extreme depression persisted, and it died about three hours after the operation, having neither vomited nor been purged during the interval.

A *post-mortem* examination was performed within two hours after death with the following results. On opening the abdomen the peritoneal cavity was found to contain no fluid, the membranes showed no evidences of inflammatory action, and the exterior surface of the intestines was extremely pale. They were, in fact, of a whitish colour and were closely packed together. The stomach contained undigested food, and the mucous membrane was pinkish and evenly congested over the whole surface. The mucous membrane of the small intestines was congested from the pylorus to the ileo-cœcal valve; it was deep pink and moist; and the villi presented the brush-like aspect

previously described in other experiments. The surface was coated with a thick layer of whitish, semi-fluid, flocculent matter, which in many cases completely choked the lumen of the gut on a cross section being made, and which on microscopic examination was found to be entirely composed of cylindrical epithelium, mingled with which were a few bacteria. The epithelial cells were in singularly perfect condition, and were either scattered or in sheets and masses. The large intestine was healthy in appearance. It contained normal fœcal matter, and the mucous membrane showed no signs of congestion or other morbid change. The mesenteric glands were of a deep pink hue internally, and contained abundance of fluid of a similar colour. This fluid on microscopic examination was found to be crowded with the cells normally present in such glands, and to contain in addition a large number of active bacteria. The latter subsequently multiplied to a great extent in a preparation which was mounted in a wax-cell.

The liver was very soft in texture, but showed no evidences of the occurrence of embolism. The spleen and kidneys were healthy, and the bladder was full of urine, containing numerous cylindrical epithelial scales and active bacteria.

On opening the thorax, the pleural cavities were found to contain no fluid, and the membranes were smooth and healthy. The lungs were pale and collapsed. There was no pericarditis. The right cavities of the heart contained dark fluid blood, and the left auricle and ventricle were empty.

Two preparations of blood were mounted in wax-cells. When examined a few minutes afterwards, one of the specimens was found to contain a sprinkling of minute, active bacteria, whilst in the other only one or two could be detected. Twenty-four hours afterwards, the former specimen was crowded with large active bacteria, which were often arranged in long series and in ramifying flakes. The other preparation also showed a considerable increase in the numbers of bacteria present, although by no means so great as had previously been observed in other similar cases.

Experiment XX.—A large healthy pariah dog was put under the influence of chloroform at 12 noon of the same day in which the previous operation was performed, and four drachms of the same fluid employed in it were injected into the right femoral vein. The operation was rapidly and successfully accomplished; there was no hæmorrhage, and the animal quickly recovered from the influence of the chloroform, and attempted to make its escape.

Shortly afterwards it became dull and depressed, and continued in that condition throughout the rest of the day. At 7 A.M. of the following day it was still somewhat dull looking, but was sitting up and drinking water freely, and at 2 P.M. it appeared to have almost entirely recovered from the effects of the operation, and was made the subject of another experiment (No. LVI) from which it also recovered.

Experiment XXI.—A pariah dog of average size was put under the influence of

chloroform immediately after the completion of the previous experiment, and four drachms of the same fluid employed in it were injected into the right femoral vein. The operation was rapidly and in every way successfully performed.

The respiration ceased whilst the wound was being stitched up, but was readily re-established, and the animal quickly recovered from the influence of the chloroform. It passed a normal evacuation soon after the operation was completed, and remained in a somewhat depressed condition throughout the rest of the day. On the following morning, however, it was much livelier, and 24 hours after the operation it appeared to be quite well, and was very desirous of effecting its escape, which it succeeded in doing not long afterwards.

(*e*)—*The choleraic matter used being* SIX *days old.*

EXPERIMENT XXII.—The dog which had previously been employed in Experiment IV was put under chloroform, and half an ounce of the supernatant fluid of the same dejection previously made use of in Experiment XV was injected into the left femoral vein. The dog appeared to be very little affected by the operation. Four days after he was in excellent health; but the wound in the thigh was still open.

Several preparations of blood were made by opening a cutaneous vein, and either treated with osmic acid and acetate of potash, or without the use of any re-agent; but in neither series could any traces of bacteria be detected.

(*f*)—*Choleraic material used being* EIGHT *days old.*

EXPERIMENT XXIII.—A strong young pariah dog was put under chloroform, and half an ounce of the fluid of the same evacuation employed in the preceding experiment injected into the right femoral vein. Owing to the slipping of a ligature, the dog lost about a couple of ounces of blood during the operation. The hæmorrhage was, however, controlled, and the dog recovered from the influence of the chloroform, but died about three hours subsequently.

A *post-mortem* examination was made within six hours after death. The abdomen was considerably distended. There were two or three ounces of reddish fluid in the peritoneal cavity, and the intestines were pinkish externally. They were distended with air, and coated with a slimy, pale pinkish material, but contained very little fluid. The liver was pale, and there were already gaseous bubbles beneath the peritoneal coat.

There was no fluid either in the pleural or pericardial sacs. The lungs were collapsed. The right cavities of the heart were distended with black blood; those of the left side were empty.

(*g*)—*Choleraic material used being* TEN *days old.*

EXPERIMENT XXIV.—A healthy, but very young pariah pup was put under chloroform, and about three drachms of the fluid of the same evacuation employed in the previous experiments (but which had now been kept for eleven days) were injected into the right femoral vein. The dog rapidly recovered from the chloroform; but there was some disturbance of the respiration, more especially immediately after the injection. The material injected was crowded with monads and bacteria, and contained numerous circular cells nearly the size of blood corpuscles and with granular contents.

The dog died 2½ hours after the operation, and a *post-mortem* examination was performed six hours afterwards. *Rigor mortis* absent. The abdomen was distended, and the peritoneal cavity contained some reddish fluid. The intestines were distended with air, but contained no liquid. The mucous membrane was, in one or two spots, coated with pinkish mucus. The liver and spleen were healthy in aspect.

The lungs were collapsed, airless and bloodless. Both sides of the heart were distended. Specimens of blood, both from the heart and from the *vena cava inferior*, showed no distinct traces of either monads or bacteria, although carefully examined for them.

(*h*)—*Material used being* TWELVE *days old.*

EXPERIMENT XXV.—A small pup was put under chloroform, and two drachms of the material used in the previous experiment were injected into the right femoral vein. Respiration ceased during the administration of the chloroform, but was re-established after it had been carried on artificially for a few minutes. Towards mid-day the dog died without having shown any choleraic symptoms, but having apparently never recovered from the *shock* of the injection.

EXPERIMENT XXVI.—A healthy dog was put under chloroform, and nearly half an ounce of a choleraic evacuation which had been passed 12 days previously injected into the median basilic vein. The operation was performed with hardly any loss of blood, and the dog rapidly recovered from the influence of the chloroform.

It did not appear to suffer from the operation, and on the following day appeared to be in perfect health. The fluid injected was swarming with bacteria and vibriones.

(*i*)—*Choleraic material used being* FIFTEEN *days old.*

EXPERIMENT XXVII.—A large healthy pariah dog was put under the influence

of chloroform, and half an ounce of choleraic fluid was injected into the right femoral vein.

The fluid was the same as that employed in Experiments XVI, XVII, and XVIII, but had now been kept for 15 days. It retained its intensely fœtid odour, but its re-action was now faintly acid. The animal rapidly recovered from the influence of the chloroform, appeared totally unaffected by the operation, and remained in perfect health for the next three days, when it was made the subject of an experiment on the effects of section of intestinal nerves.

EXPERIMENT XXVIII.—A large healthy pariah dog having been put under the influence of chloroform, three drachms of the same fluid employed in the preceding operation which had just been performed, were injected into the left femoral vein.

The dog appeared entirely unaffected by the operation, and remained quite healthy for the next three days, at the close of which period it was killed under the influence of chloroform.

An immediate *post-mortem* examination was made, and the intestines, together with the other thoracic and abdominal viscera, were found to be perfectly healthy in appearance. Some of the mesenteric glands were reserved as in Experiment XI, and were examined after 24 hours. The fluid contained in the interior of them showed an abundance of moving molecular matter, but not a single specimen of the elongated vibriones occurring in the other reserved glands.

EXPERIMENT XXIX.—A small pup, similar to those employed in Experiments XXIV and XXV, was put under chloroform, and one drachm of the evacuation employed in Experiment XX, etc., was injected into the right femoral vein. The operation was completed with perfect success and with no hæmorrhage or disturbance of the surrounding tissues. Shortly after the injection respiration ceased but was readily re-established.

After the completion of the operation the respiration was considerably disturbed. In the course of an hour or so, the animal began to whine and appeared to be in pain, moving about his limbs and turning on his back. He vomited three or four times and passed one evacuation. He died 4 hours after the operation, and a *post-mortem* examination was performed $2\frac{1}{2}$ hours after death.

Rigor mortis was strongly marked. The body was scarcely warm, and the wound was quite healthy. The peritoneal cavity contained no fluid, and the membrane was not injected. The intestines were distended, and, in greater part, of a purplish hue. They contained a pinkish, slimy substance, which, as a rule, was most highly coloured opposite the most purplish portions of the intestine. The pinkish tint of the contents did not, in this instance, correspond with the presence of patches of worms, for the latter were in several instances observed to occupy pale portions of the intestine. The liver was healthy; the kidneys were congested.

The pleural cavities contained no fluid. The lungs were collapsed, airless and bloodless. Both sides of the heart were full of blood. The blood contained active monads and distinct bacteria.

(*j*)—*Choleraic material used being* EIGHTEEN *days old.*

EXPERIMENT XXX.—A very young pup, similar to that employed in the previous experiment, was put under chloroform, and nearly one drachm of the same evacuation, which had now been kept for 18 days, was injected into the right femoral vein. The operation was performed without loss of blood; although respiration ceased, it was readily re-established, the restoration being apparently facilitated by holding the animal up by the heels. There were no symptoms of intestinal affection, but death supervened ten hours subsequent to the operation.

(*k*)—*Choleraic material being* NINETEEN *days old.*

EXPERIMENT XXXI.—A healthy dog of average size was put under the influence of chloroform, and four drachms of the same evacuation employed in the previous experiment were injected into the left femoral vein. There was no hæmorrhage, nor were the surrounding tissues disturbed. Towards the close of the operation the respiration became imperfect, but it never fairly ceased, and the animal quickly recovered from the effects of the chloroform. It did not appear to suffer from the operation, and in two days appeared to be in perfect health.

EXPERIMENT XXXII.—A healthy pup was put under the influence of chloroform, and a few drachms of the supernatant fluid of an evacuation which had remained for 19 days in the laboratory were injected into the right femoral vein. There was hardly any hæmorrhage during the operation, and the dog rapidly recovered from the influence of the chloroform. It died five hours and a half afterwards, and a *post-mortem* examination was performed three hours after death.

Rigor mortis was well marked. The abdomen was slightly swollen and there was a little colourless fluid in the peritoneal cavity. The duodenum was of a pinkish hue internally and contained thick, pale slimy matter. Further down, the contents of the intestines were watery and of a sanguineous hue. There was pink coloration throughout the jejunum and ileum, but both this and the fluidity of the contents diminished in the neighbourhood of the ileo-cœcal valve. The large intestine was normal in appearance. The liver contained numerous light coloured patches similar to those previously described in the *post-mortem* examination of Experiment XIII. It was not congested. The spleen and kidneys were normal.

The lungs were totally collapsed, airless and bloodless. The *venæ cavæ*, right auricle, and right ventricle were full of dark and light coagula. The left cavities of the heart contained a little dark coagulum.

(g)—Choleraic material used being TWENTY-TWO *days old.*

EXPERIMENT XXXIII.—A healthy dog was put under the influence of chloroform, and half an ounce of the same choleraic dejection which was employed in Experiments XXIII, etc., and which had now been kept for 22 days, was injected into the right femoral vein. The operation was performed with perfect success; the animal rapidly recovered from the influence of the chloroform, did not appear in any way to suffer from the injection, and three days subsequently was in a state of, seemingly, perfect health.

2.—INJECTIONS OF AQUEOUS SOLUTIONS OF CHOLERAIC MATERIAL INTO THE VEINS OF ANIMALS.

(a)—The solutions being recently prepared.

EXPERIMENT XXXIV.—A young pariah pup was put under the influence of chloroform at 8. A.M., and two drachms of a solution of choleraic material were injected into the right femoral vein. The solution had been prepared about half an hour before the operation, and consisted of equal measures of a perfectly fresh and filtered choleraic evacuation, and of water.

The animal rapidly recovered from the influence of the chloroform, and did not appear to be much affected by the operation. Before evening he was as lively as though nothing had happened to him, and was on the following morning made the subject of Experiment XXXVIII.

EXPERIMENT XXXV.—The pup which had two days previously been the subject of Experiment V, and which appeared to be in perfect health, was put under chloroform, and two drachms of a freshly prepared solution of choleraic evacuation were injected into the left femoral vein. The solution consisted of the supernatant fluid and a little sediment of an evacuation which had been kept for about 96 hours in the laboratory. The animal rapidly reeovered from the influence of the chloroform, was quite fresh and lively shortly afterwards, and subsequently made its escape.

EXPERIMENT XXXVI.—A healthy young pariah dog having been put under the influence of chloroform, half an ounce of an aqueous solution of choleraic material was injected into the right femoral vein. The solution was perfectly fresh, and the evacuation employed had been kept for 14 days. During the course of the day the dog passed some watery reddish evacuations; but, on the following morning, appeared healthy, and continued to do so until the third day, when he was made the subject of Experiment XL.

EXPERIMENT XXXVII.—A healthy pariah pup was put under the influence of chloroform, and a freshly prepared solution of choleraic material injected into the

right femoral vein. The evacuation employed was that which had afforded the materials for injection in Experiments XIII and XXII, and had been kept for 25 days at the time the solution was prepared. The proportions of the water and choleraic fluid in the solution were 20 minims of the latter to 1 ounce of the former.

The injection was successfully performed, and the dog rapidly recovered from the influence of the chloroform; but the respiration continued to be hurried and somewhat irregular for nearly an hour. This symptom, however, passed off, and the dog appeared not very much affected. He refused all food, however, and began to suffer from diarrhœa, passing evacuations, the first of which were normal in aspect, while the subsequent ones became more and more mucus and blood-streaked. Four hours and a half after the operation, he was observed to suffer from rigors, and these continued to occur for the next three hours, at the close of which period he died.

A *post-mortem* examination was performed two and a half hours after death. *Rigor mortis* had not set in. The body was still slightly warm and the abdomen was not distended. The parts around the wound in the thigh appeared quite healthy, and the vein above the ligature was normal in aspect and distended with fluid blood. On opening the abdomen the cavity was found to be free of fluid, and the peritoneum seemed to be quite healthy. The stomach contained glairy fluid mingled with bile. The interior of the small intestines was extremely congested, and the mucous membrane was of a deep pink colour from the duodenum to the ileo-cœcal valve. They were full of a red fluid mixed with grumous matter. This material when subjected to immediate microscopic examination showed no distinct traces of blood cells, but contained more amorphous particles with some oil globules and a few epithelial cells. The large intestine was pale and almost empty. The liver was abnormally friable, and showed numerous yellow fatty spots scattered over the surface and extending into the substance. The gall-bladder was full but not distended. The spleen appeared healthy. The medullary portion of the kidneys was very red, while the cortical substance was of a pale yellow tint and fatty aspect.

On opening the thorax, no signs of pleurisy could be detected. The lungs were totally collapsed, airless and almost bloodless. The pericardium was healthy, and contained no fluid. The right cavities of the heart were full of dark coagula and fluid blood. The left cavities were empty, and the ventricle was strongly contracted.

(*b*)—*The solutions having been prepared* TWENTY-FOUR *hours previously.*

EXPERIMENT XXXVIII.—The dog which had on the preceding day been made the subject of Experiment XXXIV without appearing in any way affected by it was again put under the influence of chloroform, and two drachms of the solution previously employed, but which was now in an active state of decomposition, containing innumerable monads, bacteria and vibriones, were injected into the left

femoral vein. The animal recovered quickly, as on the previous occasion, remained well afterwards, and was subsequently the subject of Experiment XIV.

EXPERIMENT XXXIX.—A young healthy dog was put under chloroform, and half an ounce of an aqueous solution of choleraic material injected into the right basilic vein. The solution had been prepared twenty-four hours previously, and was derived from the same evacuation as employed in Experiment XXX. The operation was successfully performed, and the dog rapidly recovered from the influence of the chloroform. Shortly afterwards well marked rigors occurred, and the animal died four hours subsequently, having passed one liquid evacuation during the interval.

A *post-mortem* examination was performed one hour and three-quarters after death. The body was still warm, and *rigor mortis* just commencing. The peritoneal cavity contained no fluid and the membrane was healthy. The mucous coat of the intestines both large and small was injected almost universally, but the contents of the guts were of a yellowish-white tint, only here and there showing a pinkish tinge. In these coloured portions the consistence of the mucous matter of which they were composed was more fluid than elsewhere. Several tortuous patches of small vessels were visible on the surface of the liver; they were gorged with blood, but the hepatic cells in their neighbourhood appeared to be unaffected in any way when examined microscopically. The spleen and kidneys were healthy.

On opening the thorax the pleural cavities were found to be quite healthy. The lungs were collapsed, airless and bloodless, and several dark extravasated patches were present in each. The heart was healthy. The right cavities were full, and the left almost empty. Specimens of blood were obtained from each side of the heart, but no distinct traces of monads or bacteria could be detected in them at the time, nor were any observed to have developed in them two days subsequently, when filaments of fungi had crept into the preparations through cracks in the covers of the wax-cells in which they were contained.

(c)—*The solutions having been prepared* FORTY-EIGHT *hours previously.*

EXPERIMENT XL.—The dog employed in Experiment XXXVI, but which now appeared to be in perfect health, and with the wound in the right foreleg clean and healing, was again put under the influence of chloroform, and five drachms of the solution used in the preceding experiment, but which had now been kept for 48 hours, were injected into the left median vein. The fluid was thoroughly shaken up previous to injection, in spite of which the animal rapidly recovered from the influence of the chloroform, and began to run about as though nothing had happened. He continued in apparent good health during the next two days, and was then made the subject of Experiment VI.

3.—Injections of organic solutions, other than of choleraic nature, into the veins of animals.

The arrangement adopted in the preceding sections will be followed out in this also, so that comparisons between the various classes of experiments may be more readily made. The introductory remarks which have been made concerning them, apply equally to this, the conditions under which they were conducted being the same; the animals were taken indiscriminately, irrespective of sex, age or strength, the solutions for injection having usually been prepared before the animals had been seen.

It will be seen that the femoral and brachial veins have been selected in preference to the veins of the neck, owing to the complications which we had, in early attempts, frequently observed to have followed the occurrence of even slight cellulitis in that region.

(*a*)—*The injecting material used while fresh.*

Experiment XLI.—A small quantity of recently drawn fowl's blood was shaken up with about its equal weight of water, and filtered; half an ounce of this filtered mixture was then injected into the right femoral vein of a young dog four months old, whilst under the influence of chloroform.

In a short time the animal recovered from the effects of the anæsthetic, and soon partook of food. Slight lameness alone indicated that anything had occurred, and on the third day he appeared quite well, when he was subjected to a repetition of the experiment (*vide* Exp. XLIX). There were no traces of blood corpuscles in the filtered solution used for injecting.

Experiment XLII.—Some freshly-drawn fowl's blood was prepared, as in the foregoing, but not filtered, so that coagula and corpuscles were sucked up into the syringe, it having been ascertained that corpuscles, as well as coagula, were retained when an attempt was made to strain off the latter through tow. The nozzle was introduced as before into the femoral vein of a powerful dog, and three fluid drachms injected into it.

The dog after recovering from the chloroform did not appear to be much affected by the operation, and three days afterwards looked so well that he was again placed on the table in order to introduce some putrefying blood, but respiration suddenly stopped, and could not be re-established. The internal organs were perfectly healthy, not the slightest evidence of embolism being manifested.

Experiment XLIII.—Three drachms of a watery solution of recently passed healthy fœcal matter, which had been five times filtered through muslin (so as to

get rid of any large particles which might have been floating in the mixture), were injected into the left femoral vein of a dog, into whose right femoral vein some putrefying blood had been injected three days previously without any very marked result, although he was evidently far from well (*vide* Exp. LIII).

The dog quickly recovered from the effects of the chloroform, took to his food readily, and by the third day was so far improved as to have managed to make his escape.

EXPERIMENT XLIV.—Half an ounce of perfectly fresh sanguineous peritonitic fluid was injected into the right femoral vein of a large healthy pariah dog which had been previously placed under chloroform. The fluid had been obtained from the peritoneum of a dog in whom peritonitis had been produced by the introduction of a solution of normal evacuation into the abdominal cavity (*vide* Exp. LXXIV).

The animal continued somewhat dull and sluggish throughout the day: the following day it was more lively, but a large inflamed swelling had appeared around the seat of the incision. On the fourth day it was very much improved, and seemed to have nearly recovered. On the fifth day it was again put under chloroform, which was pushed until respiration ceased. A *post-mortem* examination was immediately made, but not the slightest sign of peritonitis nor of embolism could be traced, the only lesion observed being the inflammatory condition of the wound in the thigh. The bladder was full of urine, and the mucous membrane of the intestines perfectly healthy.

(*b*)—*The organic solution injected being* ONE *day old.*

EXPERIMENT XLV.—A healthy young puppy was put under chloroform at 8 A.M., and three drachms of a fluid composed of mixture of water, and healthy fœcal matter which had been prepared twenty-four hours previously, were injected into the right femoral vein. The dog recovered perfectly from the effects of the anæsthetic, but died at 11 A.M. of the same day, three hours after the operation, having passed several mucous stools in the interval, although the first stool passed after the operation presented no such appearance.

A *post-mortem* examination was made at 4 P.M. of the same day, and we found that the peritoneal cavity contained reddish serous fluid. The peritoneum was not injected, and there were no signs of inflammation of the membrane. The stomach was empty, containing also about an ounce of glairy fluid, its mucous coat healthy. The duodenum was deeply congested and contained thick yellowish mucus.

The congested surface, when wiped, resembled the hairs of a hair pencil when flattened out. In the jejunum the fluid was more watery and closely resembled that found in the intestines in cholera cases. In the lower part of the ileum there was less congestion of the mucous membrane, the contents here were fœcal and

not fluid, and towards the ileo-coecal valve the surface was quite pale. The large intestine was pink and contained pinkish mucus.

There was a yellow patch at the edge of one of the lobes of the liver in which the minute vessels of the part presented a prominent tortuous appearance, evidently due to small local congestions. The spleen was large, and showed numerous soft milky nodules on section. The kidneys were normal, not congested. The lungs healthy, collapsed and scarcely crepitant; the right cavities of the heart were full, the left empty.

EXPERIMENT XLVI.—A little ordinary fœcal matter was diluted with about twice its weight of water, allowed to stand for twenty hours, and afterwards twice strained through three layers of muslin. The solution was then injected into the left femoral vein of a young dog whilst under the influence of chloroform. During the operation, the respiratory movements suddenly ceased, but were re-established after artificial respiration had been persevered in for nearly ten minutes.

The animal seemed to be quite comfortable during the day, but at night he became sluggish, passed reddish, liquid stools, and died on the following day, twenty-nine hours after the operation.

The body was examined an hour and a half after death. There were no signs of peritonitis. The stomach was empty, the duodenum contained yellowish, bile-stained fluid, and both small and large intestines contained a considerable amount of a grumous substance of the consistency and colour of black-currant jam or prune-juice, evidently due to altered blood exudation. The liver was extremely fatty. Kidneys and spleen normal. The heart was healthy, the cavities on both sides empty. There were numerous pneumonic patches interspersed throughout the lungs, but no indication of further mischief.

EXPERIMENT XLVII.—The dog used in Exp. LIX having quite recovered was put under chloroform again, and six drachms of a solution of normal evacuation, prepared twenty-four hours previously, were injected into the left femoral vein. The animal did not seem to be the least affected by this operation neither until the next day, when it became sickly, and still more so on the second day, when chloroform was again administered, and a *post-mortem* examination at once made.

There was no fluid in the peritoneum, nor the least trace of peritonitis; the intestinal mucous membrane appeared to be perfectly healthy and pale, so were the mesenteric glands, and all the other abdominal and thoracic organs.

A wax-cell preparation of the blood from the vena cava was made, and examined the next morning, when a scanty sprinkling of active bacteria were seen to be present; and on the third day the preparation was crowded with stiff short bacteroid bodies, perfectly still and resembling crystals.

EXPERIMENT XLVIII.—A very powerful pariah dog was put under chloroform, and six drachms of fluid which had been employed in the preceding experiment, ten hours previously, were injected into the right femoral vein.

The animal quickly recovered, and was under observation for three days, but not the slightest indications of functional disturbance were manifested, and it was subjected to another operation (*vide* Exp. LXII).

(*c*)—*The organic material injected being* TWO *days old.*

EXPERIMENT XLIX.—A small quantity of the solution of blood which had remained over since its employment in Exp. XLII of this series, and which was found to be in an advanced stage of decomposition, swarming with bacteria, was filtered as before, so that all solid particles together with the bacteria were got rid of, and afterwards injected into a branch of the left femoral vein of the same dog, into whose right femoral vein the fresh filtered solution had previously been injected, without ill effects (*vide* Exp. XLI).

The animal was under observation for four days, was in no way affected, eating freely any food that was placed before him.

EXPERIMENT L.—Four drachms of a decomposing solution of ordinary fœcal matter were injected into the right femoral vein of a medium-sized dog. No blood was lost, and but very little chloroform used, still the animal almost immediately after the operation began to breathe in an intermittent manner, gasped several times and died.

The body was examined immediately, in order to ascertain whether the bacteria which the solution contained, had passed through the lungs into the left side of the heart. Specimens of blood were, therefore, carefully removed from the right and from the left cavities, and on microscopic examination, we found numerous very energetic bacteria in all the specimens. The preparations of blood from the right side of the heart appeared to contain more bacteria than those from the left. All the organs were healthy, no indications existing of the cause of the sudden death.

EXPERIMENT LI.—A large healthy pariah dog was put under chloroform as usual, and six drachms of the solution of ordinary alvine discharge used in Exp. XLVII, but now forty-eight hours old, were injected into the left femoral vein. The ligature commanding the lower end of the vein unfortunately slipped, and considerable hæmorrhage ensued. It was, however, ultimately secured, and when the animal awoke it ran away.

Having been re-caught, it was kept under observation during the day, but nothing special was noted. During the night, however, the animal died, and a *post-mortem* examination was made next morning. The intestines were filled with a soft pinkish substance, consisting chiefly of epithelium, and the mucous surface of the small

intestine generally was much disorganized. The other abdominal and thoracic organs were healthy.

EXPERIMENT LII.—Immediately on completion of the preceding experiment, another huge pariah dog was put under chloroform, and six drachms of the same decomposing fluid, swarming with bacteria, injected into its right femoral vein. The animal ceased to respire almost immediately, and efforts to restore it were in vain, although it had nearly come from under the influence of the anæsthetic, and none had been administered for some time.

The viscera were forthwith exposed; the right side of the heart was enormously distended, and the left contained a little blood. The mesenteric glands were pink, and contained red blood-corpuscles. The liver was of a very dark colour and gorged with blood; other viscera healthy.

Three wax-cell preparations of the blood were made; one from the right side of the heart, another from the left side, and a third from the *left* femoral. Of these, in the first only could active bacteria be distinguished when examined immediately after the specimens were prepared; nor did any appear in the other two for some hours; next morning, however, all three contained an abundance of moving bacteria.

Two wax-cell preparations were also made of the fluid squeezed out of an axillary, and out of a mesenteric gland, both of which contained numerous active bacteria, and monads from the first, and their numbers increased greatly during the following twenty-four hours. In about four days the activity of the monads and bacteria ceased, motionless molecules alone remaining in the blood, as well as in the gland-juice preparations.

(*d*)—*The organic material injected being* THREE *days old.*

EXPERIMENT LIII.—In order to complete the series of filtered and unfiltered, fresh, and decomposed solutions of a simple organic liquid, two drachms of the decomposed watery solution of fowl's blood, which had been used in previous experiments, and had, by this time, acquired an intensely putrid odour, and swarmed with active bacteria, were injected, without previous filtration, into the right femoral vein.

Owing to various accidents the dog had to be kept under the influence of chloroform for a considerable time. Its respiration twice entirely ceased, and was, on each occasion, restored by mechanical means. At the close of the operation the abdomen was extremely distended.

In spite of these adverse circumstances, the animal on the second day was quite lively, and partook of its food freely, although the wound did not present a healthy appearance; but on the fifth day it was so far recovered as to be considered fit to undergo another operation, from which he also recovered and eventually escaped (*vide* Exp. XLIII).

EXPERIMENT LIV.—Half an ounce of the watery solution of ordinary fœcal matter which had been used in Exp. L and which now emitted an extremely fœtid odour, was injected into the femoral vein of a small young dog, but within a few minutes after the operation, although he appeared to be getting out of the influence of the chloroform, his breathing altered and was carried on by gasps. An attempt was made to draw off blood from the opposite femoral vein; but the circulation had stopped.

The viscera were at once exposed, but nothing distinctly abnormal observed. The venous system was intensely gorged with blood and both sides of the heart were distended. In the blood abstracted from the cavities of the right side, monads and bacteria were detected, but in blood removed from the axillary vein no positive evidence could be obtained of the presence of bacteria; the injected fluid would of course have had to pass through the capillaries of the lungs and of the systemic circulation before reaching the axillary vein.

EXPERIMENT LV.—A small pariah dog into whose femoral veins two different specimens of decomposing choleraic dejecta had already been injected without producing any marked result, was again placed under chloroform and half an ounce of the decomposing solution of ordinary fœcal matter (exactly as used in the last experiment (LIV), both experiments being performed on the same day) was injected into the median basilic vein.

After the operation, it is noted, "the dog appears as if nothing had happened." He was kept under observation for a week, when, in order to ascertain what changes all these putrefying matters might have produced, he was again placed under chloroform, and allowed to breath it till respiration ceased. The wounds over two of the three veins which had been tied were completely healed. There was no peritonitis, the intestines were pale and perfectly healthy, so were all the viscera except the lungs and spleen. In the former, on both sides, large patches of hepatized tissue were found evidently due to pneumonia, and, enclosed by this altered tissue, at one spot was a small cavity filled with a dark thickish fluid. In the spleen there was, near the surface of one end, a small extravasated pouch about the size of a hazel-nut.

The blood was carefully examined for monads and bacteria, but none could be found.

EXPERIMENT LVI.—Half an ounce of a decomposing solution of ordinary alvine discharge, 72 hours old, the same as used in Exp. XLVII, etc., was injected into the right femoral vein of a dog, previously brought under the influence of chloroform. Not a drop of blood was lost during the operation.

There were not the slightest manifestations of illness during the three days the animal was kept under observation, and when the viscera were examined after it had been killed under chloroform, they were all found to be perfectly healthy.

A wax-cell preparation of the blood was kept under observation for three days, but no bacteria nor any other organisms developed. A similar preparation was made by squeezing some fluid out of a mesenteric gland; here also no monads or bacteria could be detected during the period above named.

EXPERIMENT LVII.—The subject of Exp. XX, a large pariah dog, into whose right femoral vein decomposing choleraic fluid had been introduced five days previously without producing serious illness, was put again under the influence of chloroform, and six drachms of a solution of normal fœcal matter injected into the other femoral vein. Neither was the animal much affected by this, and four days afterwards appeared to be in perfect health, when it was killed under chloroform and immediately examined.

The thoracic and abdominal viscera were normal, and the mucous coat of the intestines quite unaffected. A wax-cell preparation of blood from the heart appeared to be a perfectly healthy sample; there were no bacteria visible, nor were any developed during the following two days. A similar preparation was made of the fluid in the mesenteric glands (which was very abundant); on the first day no distinct bacteria were visible, but on the following morning the preparation was crowded with very active large bacteria, together with long, active, and still oscillatoria-like vibriones, such as are depicted in Fig. 1, page 88; on the third day these organisms were all motionless and degenerated into a beaded leptothrix network (Fig. 2, page 88).

(*e*)—*The injected material being* FOUR *days old.*

EXPERIMENT LVIII.—A large healthy pariah dog was brought under the influence of chloroform, and four drachms of a solution of healthy alvine discharge, which had been prepared 96 hours previously, were injected into its right femoral vein. The dog rapidly recovered, and seemed to be but little affected.

Presently, it appeared to become drowsy, and in the course of half an hour symptoms of great irritation of the bowels were manifested. The animal was evidently much griped, and passed several mucous stools mixed with blood. This it continued to do during the day, numerous gelatinous flocculi also being mixed with the dejections. The flocculi when subjected to microscopic examination consisted of exudation cells (similar to those occurring in the flocculi of cholera dejecta), together with a few epithelial cells and structureless gelatinous material.

Thirteen hours after the operation the dog died, and a *post-mortem* examination was made immediately. No fluid in peritoneum, no evidence of peritonitis; mesenteric glands much enlarged: dark pink internally and containing fluid of a similar colour. The small intestines were very pale externally, whereas the mucous surface was of a dark pink colour, being coated with a reddish mucous substance, which on removal showed the epithelial coat unaffected, and the mucous membrane not congested. No further evidence of morbid change could be discovered.

EXPERIMENT LIX.—Four drachms of the alvine solution, 96 hours old, as used in the last experiment, were injected into the right femoral vein of a moderate sized dog under chloroform. The dog continued to be very active for some time, and attempted to make his escape, and was evidently by no means so much affected as the previous animal. By the next day it appeared to be quite well, and some more decomposing material was introduced into its circulation without producing any effect (*vide* Exp. XLVII).

EXPERIMENT LX.—A large healthy dog placed under chloroform, and four drachms of the solution used in the two previous experiments were introduced into the right femoral vein. There was no loss of blood. It continued drowsy for a considerable time, but recovered during the course of the day, and by the fifth day was so far recovered as to seem fit to undergo another operation (*vide* Exp. LXIII).

EXPERIMENT LXI.—A small healthy pariah dog was put under chloroform, and five drachms of the solution of ordinary fœcal matter used in Exp. LVII, etc., now 96 hours old, were injected into the right femoral vein very successfully. The animal died within a few hours, and a *post-mortem* examination was made.

There was slight injection of the diaphragmatic pleura close to the pericardium, otherwise there were no indications of disease. The intestines were perfectly healthy.

Wax-cell preparations of blood from the heart and of fluid from the mesenteric glands were under observation for four days. The blood specimen continued perfectly free from all moving particles whatever, and contained no distinct motionless bacteria; whereas the gland-juice preparation was swarming with bacteria on the second day.

EXPERIMENT LXII.—As the dog used in Exp. XLVIII appeared to be vigorous and in excellent health, he was again put under chloroform, and six drachms of the same fluid as was used on the previous occasion, but now farther advanced in decomposition, being 96 hours old, were injected into the left femoral vein; on the third day he appeared to be perfectly well again, and when examined after being killed under chloroform, all the organs, including the intestines, appeared to be in a healthy condition.

A wax-cell preparation of the blood and another of fluid derived from the mesenteric glands were kept under observation for three days, but no moving bodies of any kind, monads or bacteria, were seen from first to last.

EXPERIMENT LXIII.—The powerful dog used in Exp. LX looked so well on the following day, as to be considered fit to undergo another operation, consequently having been brought under the influence of chloroform, six drachms of the solution of fœcal matter used in Exp. LVII, now 96 hours old, were injected into the remaining femoral vein.

The animal very quickly recovered from this also, and on the third day was

killed in order to note the condition of the viscera. No lesion whatever could be found.

A drop of blood was carefully removed from the right external iliac vein and placed in a wax-cell, and a drop of fluid from the interior of a mesenteric gland was similarly enclosed for observation. During the three days that they were thus watched, not a single distinct monad nor bacterium was seen in either of the specimens.

EXPERIMENT LXIV.—A large pariah dog was placed under chloroform, and an ounce of the same solution as used in Exp. LVIII, etc., 100 hours old, was injected into the right femoral vein. It continued drowsy for some time, vomited a large quantity of bilious matter, and by the next day was tolerably well. The wound, however, had assumed an unhealthy, sloughy appearance, so the animal was killed forthwith. There was no peritonitis, the intestines were normal in every way, so were all the other viscera, thoracic and abdominal. The bladder was full.

A wax-cell preparation of a drop of blood removed from the external iliac vein of the unwounded side, and a similar preparation of fluid pressed out of a mesenteric gland, were kept under observation for three days, during which period neither monads nor bacteria were seen in the former, but an abundance of white cells, whereas in the latter a few bacteria eventually appeared.

EXPERIMENT LXV.—A large healthy pariah dog was placed under chloroform, and five drachms of precisely the same fluid as used in the last experiment were injected into its left femoral vein. After the operation it seemed to be much depressed, and vomited several times. The animal continued in this condition for two and a half hours, when it died.

A *post-mortem* examination was immediately made, and it was found that the small intestines, though very pale externally, were internally deeply congested, and the lumen of the gut choked with a semi-fluid slimy substance, consisting chiefly of detached epithelium, the individual cells being in a perfect state of preservation. Beneath this substance the villi were seen to be deeply congested, presenting a brush-like appearance. The stomach was healthy, and so was the large intestine. The mesenteric glands looked healthy, and so did the remainder of the abdominal viscera. There was no peritonitis nor pleuritis, but there seemed to be some slight pericarditis. The lungs were collapsed and pale, and both sides of the heart contained fluid blood.

(*f*)—*The injected material being* FIVE *days old.*

EXPERIMENT LXVI.—A powerful pariah dog was placed under chloroform, and half an ounce of the decomposing solution of fœcal matter used in Exp. LIV,

etc., was injected into the right median-basilic vein. During the operation the animal on two occasions ceased to breathe, but was each time speedily brought round by artificial respiration.

On the following day the dog appeared to be perfectly well, and made his escape.

(g)—The injecting material being SEVEN *days old.*

EXPERIMENT LXVII.—The dog referred to in the last experiment was caught towards the evening of the day on which he made his escape, and on the following morning placed under chloroform, when six drachms of the same fluid as had already been introduced into its circulation, but now two days older, which had since remained in an uncorked bottle, and was swarming with bacteria and vibriones, were injected into the other median-basilic vein.

During the four succeeding days the animal was closely watched, but he appeared to have been in no way affected.

Having been killed under chloroform, the viscera were carefully examined, but no lesion detected anywhere, nor were there any signs of deposit in the lungs, liver or other organs. Three preparations of blood were obtained from a thoracic vein, and examined immediately, but not a single bacterium could be detected, nor were there any developed in the cells, although under observation for a week.

B.—Experiments on the Introduction of Choleraic and of other Organic solutions into the Peritoneal cavity of animals.

When the series of experiments on the effects of the introduction of solutions of alvine discharges directly into the circulation, as recorded in the previous pages, had been carried on for some time, we debated whether we should at once proceed to repeat similar experiments with solutions of various other organic and of inorganic substances, of acid, alkaline or neutral re-actions, or whether we should continue to use the same infecting medium, varying the mode by which its introduction into the system was effected.

Having satisfied ourselves that putrefying matter introduced directly in the blood, did very frequently exert as direct an action on the mucous membrane of the small intestine, as, for example, mercury exerts on the mucous lining of the mouth and on the salivary glands, or as atropia and calabar bean exert on the iris, we yet felt convinced that the physiological phenomena evoked, and the pathological changes induced, were not those of cholera, although appearing to present a certain though, distant, relation to them.

Although some remedial agents act in pretty much the same way, no matter how introduced into the system, whether by the mouth, lungs or through the skin, such as mercury and turpentine, the former increasing the salivary secretion, and the

latter the urinary, still, their actions are to some extent modified by the mode of administration. We were, therefore, anxious, in the first place, to ascertain whether the introduction of precisely the same media, through some other channel, would modify their action on the system, in such a way as to bring the results to approximate more closely to the features presented in cholera, and in the second, whether the effects produced by one kind of alvine discharge could, in any way, be distinguished from those of another.

With these ends in view we conducted the following series of experiments on the effects of the introduction of organic fluids into the peritoneal cavity.*

EXPERIMENT LXVIII.—A large, healthy pariah dog was put under the influence of chloroform at 8-30 A.M., and one ounce of choleraic evacuation in a state of decomposition (having been kept for 96 hours) was injected into the peritoneal cavity. Previous to injection a preparation of the blood was mounted in a wax-cell; shortly after the operation the animal was observed to suffer from well marked rigors, which recurred at intervals throughout the course of the day.

It remained in a state of extreme depression, lying in a semi-drowsy condition, and neither whining nor showing any other symptom of pain or uneasiness. A close watch was kept on the symptoms throughout the whole day, but nothing new presented itself; there was no passage of urine, nor of dejecta, and the only change observed was a gradual increase in the depression and drowsiness. Towards evening the animal appeared to be rapidly becoming weaker and could not stand on its legs, but the limbs were quite lax and showed not the slightest evidence of cramps. It seemed to suffer from thirst, and drank water freely when offered to it.

As it appeared to be very improbable that life would be prolonged until the following morning, chloroform was again administered at 7 P.M. and continued until respiration had ceased. A *post-mortem* examination was then performed immediately with the following results.

On opening the abdomen the cavity was found to be distended with sanguineous fluid. This fluid was subjected to careful microscopic examination. It contained a few red blood-corpuscles and myriads of very active amœboid bioplasts, which in many cases, until their movements and changes of form were observed, presented a curiously marked resemblance to cylindrical epithelial cells. Many others, however, were ragged in outline, and passed off into long thread-like extensions. The fluid surrounding the cells was very clear, hardly any molecular matter could be detected in it, and only here and there was a minute tremulous monad to be seen.

The peritoneum and mesentery were intensely injected and thickened, but there was no distinct evidence of the presence of solid exudative flakes between the viscera.

* The results of introduction of such materials into the system through the mucous membrane of the lungs will be made the subject of experiment shortly.

The stomach contained about ten ounces of glairy fluid, its mucous surface appeared to be perfectly healthy, there were no points of extravasation present, and the vessels were not injected. The duodenum also appeared to be healthy and contained some bilious fluid. The mucous membrane of the jejunum was coated with a dark layer of what appeared to be inspissated blood. This layer became more and more marked lower down, and attained its maximum development in the ileum, where it was of the consistence of treacle and of a dark tarry colour. This dark layer could be pealed off the surface of the mucous membrane, leaving the latter dry, but otherwise quite healthy in appearance. The tarry coating ceased abruptly about a foot above the ileo-cœcal valve and was replaced by one composed of the common, whitish, gelatinous mucus normally lining the intestines in dogs. The mucous membrane here also appeared quite healthy, and there was neither extravasation nor any evidences of detachment of epithelium present. The walls of the lower extremity of the ileum and those of the appendix vermiformis were considerably thickened. The large intestine appeared healthy internally.

The tarry and pale mucous coatings on the interior of the small intestine, together with the subjacent layers of the mucous membrane, were subjected to careful microscopic examination. The tarry layer consisted of a gelatinous, molecular, more or less fibrillated basis identical in appearance with that of the normal flakes of intestinal mucus. In, and on this, were innumerable blood-crystals, a few indistinct bioplastic masses and various particles of intestinal contents together with large numbers of ova. Not a single red blood-corpuscle was visible in spite of the extreme profusion of blood-crystals, and the distinct sanguineous hue, that even the thinnest layers, into which the material could be spread out, retained. The whitish-grey coating, replacing the former one at the lower end of the ileum, was identical in appearance and structure with it, minus the red colour and the abundant blood-crystals, and was, in reality, what it appeared to be at first sight, namely, the normal thick mucus of the gut.

The material scraped from the mucous surfaces beneath these layers consisted entirely of distinct cylindrical epithelial cells and of detached villi, many of which showed their epithelial coating firmly and evenly attached, even after the violence to which they had been subjected.

There was not the slightest resemblance between the microscopic characters of this layer and those of the superincumbent one, whether the latter were of normal aspect as at the lower end of the ileum, or deeply blood-stained and tarry as farther up.

The liver was dark in colour and very full of blood, but no farther change could be detected in it. The remaining abdominal organs were congested, but no special lesion could be detected in any of them. The bladder was full of urine.

On opening the thorax, the pleural cavities were found to be free from fluid. The lungs were collapsed and healthy in texture. The heart was healthy, the right

cavities full, but not distended with fluid blood, and the auricle and ventricle empty.

A preparation of blood from the right side of the heart was mounted in a wax-cell and set aside for further examination, along with the preparation procured previous to the operation. Both preparations were examined on the following morning at 9 A.M., when the one had been kept for above twenty-four and the other for about fourteen hours. On examination the former was found to be quite free from bacteria, and to contain very abundant bioplasts in the pus-like condition previously alluded to, whilst the latter only differed from it in there being rather fewer bioplasts free in the serum. They were again carefully examined two days subsequently. They both remained very fluid in consistence, very few bioplasts were present in a distinctly defined condition, they were aggregated in masses, and appeared to be rapidly undergoing disintegration. Neither bacteria nor active molecules could be anywhere detected in either preparation. On subsequent examination the only changes observed in either specimen were gradual disintegration, and there was no development of bacteria in them.

EXPERIMENT LXIX.—At 12 noon of the same day in which the preceding experiment was performed, chloroform was administered to another large healthy pariah dog, and about one ounce of the same choleraic material was injected into the peritoneal cavity through a canula. The dog soon recovered from the primary effects of the operation, and was not affected by such distinctly marked rigors as the former animal.

His general demeanour, however, was precisely similar to that observed as the result of the other operation; he was profoundly depressed, lying perfectly quiet and neither whining nor showing any other indication of pain. Neither fœces nor urine were passed throughout the whole day, and there were no evidences of spasm of any of the muscles. As he appeared fully less depressed than the other dog, it was decided to allow him the chance of surviving until the next morning, and his condition at that time had not materially altered, the only change perceptible being an apparent increase in the depression.

Chloroform was, accordingly, again administered at 7-30 A.M., 19½ hours after the operation, and the administration carried on until respiration ceased.

The abdomen was opened before complete cessation of respiration and circulation. The cavity was distended with fluid of a somewhat less marked sanguineous hue than that present in the previous experiment, but, otherwise, it presented the same characters both to the unaided eye and when subjected to microscopic examination. The peritoneum, both visceral and parietal, presented well marked signs of inflammation, and the vessels on the intestines were highly injected and very red.

There were a few shreds of soft lymph diffused over the surface of the liver, which, on microscopic examination, were found to consist of aggregations of more or

less spherical corpuscles, identical in appearance, and probably also in nature with those present in such abundance in the fluid after the active, vital, amœboid movements had ceased. The resemblance of such threads of soft lymph to the flocculi contained in choleraic evacuations, cannot fail to strike any observer even at the first glance.

The mucous membrane of the stomach was healthy. The duodenum was also normal in aspect, and contained a little bile. The jejunum and ileum presented precisely the same phenomena as those present in the previous case, but to an even more marked degree, as, towards the middle of the ileum, the cavity of the gut contained tarry fluid in addition to the sanguineous coating of the mucous membrane. Towards the lower extremity of the ileum the walls of the intestine appeared to be considerably thickened. For a few inches above the ileo-cœcal valve the tarry coating was absent, and was replaced by a layer of the normal thick intestinal mucus.

Specimens of these layers, and of the mucous membrane beneath them, were, in this instance also, carefully examined under the microscope, and their nature was found to be precisely similar. Here also the effusion had taken place without impairing the integrity of the epithelial coat of the mucous membrane in the slightest degree, the latter presenting a remarkably dry and firm aspect when the exudative layer was peeled off from it, and it was most remarkable to observe the very small number of epithelial cells which adhered to the latter in spite of the violence involved in the separation.

The large intestine contained a larger quantity of dark coloured fluid than was present in the previous case, but the gut was not affected in any way equally with the small intestine.

The rest of the abdominal organs were congested, but showed no other lesions of any kind.

The bladder was full.

The heart was healthy in appearance. A specimen of blood from the right ventricle was mounted in a wax-cell. When examined, eight hours after preparation, it was found to contain a considerable number of leucocytes, some of which were of large size, whilst others were still exhibiting amœboid movements. No distinct evidences of the presence of bacteria could be detected, although they were especially searched for with a $\frac{1}{8}$th immersion lens, nor did any appearances of the development of such bodies present themselves during the next four days, whilst the preparation was kept under observation.

EXPERIMENT LXX.—A large healthy pariah dog was put under the influence of chloroform at 11-30 A.M., and one ounce of a watery solution of the sediment of the choleraic evacuation employed in the two preceding experiments, and which had now been kept for seven days, was injected into the peritoneal cavity.

The animal appeared to be very little affected by the operation, had no rigors

after it, showed no symptoms of pain, and in the afternoon ran home along with the servant, who had the charge of the dogs, to his hut in a village, about half a mile off. On the following morning he was brought back, and at this time also appeared in no way affected by the operation. Chloroform was administered until respiration ceased, and a *post-mortem* examination was then immediately performed, nearly 24 hours after the injection had taken place.

On opening the abdomen about three ounces of pinkish-grey fluid were found in the peritoneal cavity. The mesentery was thickened and injected, and there were a few small patches of soft lymph on the liver. The walls of the intestines appeared to be slightly thickened, but they were otherwise normal in appearance. The bladder was distended with fluid. The rest of the abdominal and thoracic viscera appeared to be quite healthy.

EXPERIMENT LXXI.—A strong healthy pariah dog was put under the influence of chloroform at 8 A.M., and half an ounce of a solution of a normal evacuation was injected into the peritoneal cavity. The solution had been prepared three days previously, and was in an active state of decomposition.

The dog was kept under close observation for seven hours, during which it showed no marked symptoms of any kind, and then went home with the man in charge, walking along with him without manifesting any symptoms of pain or inconvenience. The man brought its body next morning, and stated that, soon after he took it to his house, it suffered from severe rigors, and that it died about eight hours afterwards without having shown any other decided symptoms.

There was no vomiting, and no evacuations were passed subsequent to the operation. A *post-mortem* examination was performed eight hours after the occurrence of death.

On opening the abdomen, extensive signs of peritonitis presented themselves. The cavity contained an abundance of fluid of a reddish tint and somewhat thick consistence. When subjected to microscopic examination, it was found to contain a few red blood-corpuscles, and very numerous granular pyoid cells of a more or less circular form. They were all perfectly motionless, seemingly dead, and the fluid surrounding them was crowded with active bacteria and vibriones.

The interior of the small intestines presented the appearances previously described in Experiments LXVIII and LXIX. There was a continuous coating of a dark tarry aspect beneath which the epithelial surface appeared quite healthy. As before, about six inches of the ileum, immediately above the ileo-cœcal valve, was unaffected. The large intestine also was covered with a coating of tarry material.

No other noteworthy lesion was to be found in any of the abdominal or thoracic organs. There was no pleurisy.

Specimens of blood from the right ventricle were found to contain a few bacteria when subjected to careful examination under a $\frac{1}{12}$th immersion lens.

EXPERIMENT LXXII.—An extremely powerful pariah dog was, with much difficulty, brought under the influence of chloroform at 8 A.M., and about six drachms of a decomposing solution of beef were injected into the peritoneal cavity. The solution had been prepared ninety-six hours previously, and at the time of the injection was of an intensely fetid odour and swarming with active bacteria and short vibriones.

The dog was somewhat dull and depressed throughout the course of the day, but on the following morning he did not appear to have become any worse, and was still so strong, as to give much trouble whilst chloroform was again administered until the cessation of respiration.

A *post-mortem* examination was then performed at once, 24 hours after the injection of the fluid had taken place. On opening the abdomen the cavity was found to contain about two ounces of red serous fluid almost resembling pure blood in appearance. A preparation of this fluid was mounted in a wax-cell and examined one hour afterwards. It was then found to contain numerous red blood-corpuscles and myriads of active amœboid bioplasts, but no bacteria could be detected in it although they were specially searched for under a $\frac{1}{8}$th immersion lens.

On the following day, however, there were plenty of active bacteria present. The red corpuscles remained unchanged; but the bioplasts had lost all amœboid motion, had assumed a more or less spherical form, and were in process of disintegration. By the following morning the activity of the bacteria had ceased, and shortly afterwards the preparation dried up.

The intestines were congested externally, and their internal surface presented patches of the tarry sanguineous effusion described as occurring in the preceding Experiments Nos. LXVIII, LXIX, etc. The appendix vermiformis was of very large size, but appeared to be quite healthy. The rest of the abdominal and thoracic viscera appeared not to be affected in any way, and the bladder was full of urine.

A specimen of blood from the right ventricle was mounted in a wax-cell and examined an hour afterwards. No monads or bacteria could be detected in it, but an abundance of delicate, active white corpuscles were present. The preparation was kept under observation for some days, but there was no indication of the development of bacteria in it.

EXPERIMENT LXXIII.—A healthy pariah dog was put under the influence of chloroform, and four drachms of the fluid from the peritoneal cavity of the dog of Experiment No. LXXII were injected into the abdomen. The fluid had been obtained at the *post-mortem* examination in the above experiment, which was performed immediately before the injection took place.

The animal rapidly recovered from the influence of the chloroform, and appeared to be little affected by the operation. It remained quiet during the day, showing no symptoms of pain, or of cramps, but it vomited once or twice. Death occurred during

the early part of the night, and a *post-mortem* examination was performed on the following morning.

On opening the abdomen, the peritoneum was found to be extremely congested, and the cavity contained a considerable amount of sero-sanguinolent fluid. A preparation of this fluid was mounted in a wax-cell as usual and examined about an hour afterwards. It was then found to be swarming with very active bacteria, and to contain a few red blood-corpuscles, together with numerous small pyoid corpuscles in a state of disintegration. When again examined, after the lapse of a few hours, the bacteria were observed in unimpaired activity, and the breaking up of the pyoid corpuscles appeared to be progressing rapidly, many of them containing from one to three granular rings or Nuclei in their interior; whilst in many such cells the molecules between the rings or Nuclei and the outer pellicle were in active swarming motion.

On the following day almost all the corpuscles had disappeared or had become uniformly granular, and the movements of the bacteria had become more sluggish. The preparation was kept under observation for several days; but the only further changes observed to take place in it were a progressive disintegration of the granular corpuscles and a gradual diminution in the activity of the bacteria.

The intestines were coated internally with a sanguineous layer of a deep prune-juice colour. The rest of the abdominal viscera appeared to be unaffected. On opening the thorax, there was found to be no pleurisy; the pleural cavities contained no fluid, and the lungs were quite healthy. The pericardium was injected and contained reddish serous fluid. The heart was normal.

A preparation of blood from the right ventricle was mounted, as usual, in a wax-cell. When examined, about an hour afterwards, nothing abnormal was detected in it. After the lapse of a few hours, the preparation was again examined. Crystals had begun to form along the margin; there was only a narrow ring of free serum, and very few white corpuscles were visible. At first no monads or bacteria could be detected; but a rapid development of very delicate vibriones took place, whilst the preparation was under observation. They were elongated, of extreme tenuity and of great activity. On the following day the serum was swarming with the bodies described above. They remained very active, and their delicacy was so great as to necessitate most careful management of the light, in order to render them visible. No further development occurred; and the only changes subsequently observed were gradual diminution in the activity of the vibriones together with breaking up of the small number of white cells present in the serum.

Experiment LXXIV.—Whilst the *post-mortem* examination described in the previous experiment was being performed, a syringe was filled with the fluid contained in the peritoneal cavity, and another powerful pariah having been subjected to the influence of chloroform, about one ounce of this fluid was injected into the abdomen. During the operation, respiration and circulation ceased for a short time, but they

were easily re-established, and the dog rapidly recovered from the influence of the chloroform. At first, it appeared to be very little affected by the injection; but it rapidly passed into a state of extreme depression, and died five hours after the operation.

A *post-mortem* examination was performed two hours after death, with the following results. *Rigor mortis* had just begun to set in, but the tissues were still warm. On opening the abdomen, there was found to be very marked peritonitis. There was a large quantity of red fluid in the abdominal cavity.

When a preparation of this fluid, mounted in a wax-cell, was examined an hour after its removal from the body, it was found to be crowded with minute, slightly moving bacteria and monads, and to contain masses of very small disintegrating pyoid corpuscles, together with numerous free oil-globules. The preparation was kept under observation for several days; but no further developments occurred, and the activity of the bacteria gradually ceased. The intestines were rough and injected externally; but, when laid open, they did not show nearly so much of the prune-juice exudation as had been observed in other previous instances. The condition of the mucous surface as regarded exudation closely corresponded with that observed in the case of the dog into the peritoneal cavity of which decomposing beef-juice had been injected (*vide* Experiment LXXII). The rest of the abdominal organs appeared to be quite healthy.

On opening the thorax, there was found to be well marked injection of the pericardium, especially on its external surface; but the pleuræ, lungs and heart were unaffected. A preparation of blood from the right ventricle was examined an hour afterwards, and was found to be full of very minute active particles. No further development of these bodies was detected during the subsequent few days in which the preparation was preserved.

EXPERIMENT LXXV.—Chloroform having been administered to a strong healthy pariah dog, an ounce of a decomposing solution of normal evacuation was injected into the peritoneal cavity. The solution employed had been kept for six hours in a wide-necked bottle which was loosely plugged with cotton-wool, in order to keep flies and other insects out.

The animal rapidly recovered from the influence of the chloroform and showed no symptoms of pain or of cramps, but after some time it passed some bloody mucous evacuations.

It was killed with chloroform fourteen hours after the injection, and a *post-mortem* examination was performed at once. On opening the abdomen, the peritoneum was found to be intensely inflamed and thickened, and flakes of soft lymph were adhering to the liver and other viscera. The cavity contained about a pint of sanguineous fluid. A preparation of this fluid in a wax-cell was examined two hours subsequent to its removal from the abdomen; it was found to consist of a clear fluid crowded with

bodies resembling the white corpuscles of the blood, and containing numerous red blood-corpuscles also. More than half of the white cells were still actively emitting long stringy protrusions. There were numerous delicate fibrinoid threads netted through the preparation, but although a careful search was made for them with the $\frac{1}{8}$th immersion lens, neither bacteria nor vibriones could be anywhere discovered in it. Three hours afterwards, however, a few motionless bacteroid bodies were observed in it, and twenty-four hours after, a few moving bacteria were present, and the field was covered with elongated motionless vibriones (Leptothrix?).

When the small intestines were laid open, the ileum immediately above the ileo-cœcal valve was found to present a perfectly normal aspect, but throughout the rest of the gut the mucous membrane was coated with a tarry layer similar to that observed and described in several previous cases. As before, this was found on microscopic examination to consist of the normal tough intestinal mucus crowded with blood-crystals and containing a few white granular cells, but entirely devoid of red blood-corpuscles and epithelial cells. There was no detachment of epithelium, and on peeling off the bloody, mucous layer, the epithelial coat was exposed quite intact and merely characterised by a certain dryness of appearance. The large intestine was unaffected, and the rest of the abdominal organs appeared to be healthy. The bladder was full of urine.

On opening the thorax the lungs and pleuræ were found to be perfectly healthy, but the pericardium was injected, and there were deposits of lymph on its surface. The heart did not present any abnormal appearances.

A preparation of blood from the heart was, as usual, mounted in a wax-cell. When examined, an hour afterwards, no traces of monads or bacteria could be detected in it. Three hours subsequently it was again examined, and one or two moving molecules, together with some still ones, were then detected, whilst very few white corpuscles had crawled out into the serum. On the following day there was an abundance of active bacteria in the serum; they continued in motion throughout that day, but had all become still when the preparation was again examined on the subsequent morning.

Experiment LXXVI.—A very powerful pariah dog was put under the influence of chloroform, and one ounce of the peritonitic fluid obtained from the abdominal cavity of the dog of Experiment LXXII, and which had been previously employed in Experiment LXXIII, was injected into the peritoneal cavity. This fluid had been kept in an open gallipot for thirty-six hours at the time when the injection was performed.

The dog rapidly recovered from the influence of the chloroform, and remained somewhat dull and sluggish throughout the course of the evening. It did not, however, show any symptoms of pain or cramps, and on the following morning, about fifteen hours after the injection, it did not appear to be any worse.

It was accordingly killed with chloroform, and a *post-mortem* examination was performed at once. The appearances which presented themselves did not differ materially from those described in connection with the preceding experiments. Preparations of the peritoneal fluid and of the blood were, as usual, mounted in wax-cells. The peritoneal fluid was examined an hour after its removal from the body, and was then found to contain an abundance of minute active bacteria. There were also numerous bioplasts and red blood-corpuscles, the former of irregular shape, and showing slow changes in form only. Three hours afterwards the bacteria continued in activity, the bioplasts were very ragged in outline, and there were now numerous groups of delicate, beaded, motionless threads resembling leptothrix, present. On the following day these threads had disappeared, and the preparation was crowded with bacteria and monads, some of which were motionless, whilst others were in full activity.

The preparation of the blood was also examined an hour after it had been set up. It then showed no distinct bacteria, but contained numerous minute, motionless molecules. It was again examined after an interval of three hours, and a few active molecules, together with two very active short vibriones, were observed in the serous ring. Only two or three white cells had crept out. A second preparation, however, at this time contained an abundance of free white cells, and showed neither active molecules nor bacteria. On the following day the former preparation showed some patches of still molecules: the latter now contained a few active bacteria. No further developments occurred in either of these preparations subsequently.

EXPERIMENT LXXVII.—A healthy pariah dog was put under the influence of chloroform at 8-30 A.M., and half an ounce of peritonitic fluid which had immediately before been removed from the abdominal cavity of the dog of Experiment LXXV was injected into the abdomen. The animal appeared to be somewhat dull and depressed for a short time, but in the afternoon it seemed to have entirely recovered from the effects of the operation. It continued in apparent health throughout the following day, and was killed with chloroform on the next morning, 48 hours after the injection.

A *post-mortem* examination was performed at once, but no lesions could be detected. There was no peritonitis, and all the organs were quite healthy in aspect.

EXPERIMENT LXXVIII.—A large healthy pariah dog was put under the influence of chloroform, and an ounce of the supernatant fluid of a solution of healthy evacuation was injected into the peritoneal cavity. The solution was that employed in Experiment LXXV, and was at the time of injection 72 hours old. It had been retained as before in a wide-necked bottle plugged loosely with cotton-wool.

The dog was dull and depressed during the day, but drank water freely in the

evening, and on the following morning, 24 hours after the operation, it appeared to be perfectly well. It was, accordingly, again put under chloroform and the abdominal cavity opened. There was considerable inflammation of the parietal peritoneum, the mesentery and intestines were intensely injected and inflamed, but there was no fluid present.

A loop of the small intestine was ligatured, the ligatured portion filled with tepid water, by means of a pointed syringe introduced through the walls, and the gut returned to the abdomen, which was then sewn up. The administration of chloroform was then continued, and the animal died under its influence after an hour.

A *post-mortem* examination was performed about half an hour after death. The interior surface of the small intestines with the exception of the ligatured loop was intensely congested, the latter portion had lost all traces of congestion, presented a macerated appearance, and was covered with a layer of soft pale loose epithelium. No other changes observed.

EXPERIMENT LXXIX.—A healthy pariah dog was put under the influence of chloroform, and one ounce of a choleraic evacuation, which had been passed by a patient in hospital a few minutes previously, was injected into the peritoneal cavity. The fluid employed was the same as that used in Experiment I of the series of injections into the veins, and the two operations were performed at the same time.

The animal appeared to be very little affected by the operation, continued in the same condition throughout the course of the day, and on the following morning, twenty-four hours after the injection, seemed to be quite well.

It was, accordingly, again put under the influence of chloroform and the abdominal cavity opened. It contained an abundance of yellowish watery fluid, which, on microscopic examination, was found to be full of exudation-cells and perfectly free from bacteria. The parietal peritoneum was densely injected and showed distinct evidences of healing peritonitis.

The small intestine was deeply congested. A loop of it having been ligatured, a solution of salt and water was injected into the ligatured portion. The intestine was then returned and the abdomen closed.

The administration of chloroform was continued, and the animal killed at the close of an hour. The ligatured loop of intestine was found to be full of fluid, no absorption appearing to have occurred. The interior surface was coated with white gelatinous matter, and flocculi of a similar nature were floating in the fluid.

These flocculi were found, on microscopic examination, to be mainly composed of epithelium, and, when the gelatinous coating was scraped off, the mucous membrane beneath it was found to be deeply congested. The rest of the intestine was intensely congested, and showed patches of the prune-juice coating so characteristic of the

mucous membrane of the gut in peritonitis induced by the injection of fluids into the abdominal cavity.

C.—A short review of the preceding experiments.

In attempting a short analysis of the preceding series of experiments, it will perhaps be as good an arrangement as any to adhere to the classification already adopted in their narration.

A Table showing the number of experiments with undiluted choleraic material, the mortality, and the principal lesions produced by its introduction into the veins of dogs.

Age of choleraic material injected.	Number of experiments.	Number of Recoveries.	Number of Deaths.	Number in which the *intestines* were affected.	Number in which the *pericardium* was affected.	Number in which *embolism* was detected.	Remarks.
Quite recent ...	1	...	1	...	...	1	
One day	2	2	...	1	...	...	Erysipelas attacked the wound.
Two days ...	3	3	...	...	...	...	
Three „ ..	4	1	3	3	1	...	
Four „ ...	11	5	6	7	2	2	
Six „ ...	1	1	...	...	...	...	Pleurisy present in one.
Eight „ ...	1	...	1	1	...	...	
Ten „ ...	1	...	1	...	...	...	
Twelve „ ...	2	1	1	...	...	...	Death from shock.
Fifteen „ ...	3	2	1	1	...	...	„ „ „
Eighteen „ ...	1	...	1	...	...	...	
Nineteen „ ...	2	1	1	1	...	...	
Twenty-two days ...	1	1	...	...	...	...	
Total	33	17	16	14	3	3	

1. Thirty-three experiments have been described, more or less in detail, in connection with the introduction of small quantities of the alvine discharges of cholera patients, unmodified by any admixture, into the veins of dogs of various size and age; whereas seven others are given in which the choleraic injecting material had been diluted with water. Thirty-two dogs were made use of in carrying out these series of thirty-three experiments, one dog having been resorted to on two occasions for the same purpose; whereas some of the others had either already been

operated upon, or were so in another class of experiments subsequently undertaken.

In these thirty-two experiments sixteen deaths occurred: thirteen evidently from the direct action of the putrefying material exerted through or upon the blood; two apparently from shock, and one dog was killed owing to erysipelatous inflammation of a severe kind attacking the wound. These are consequently left out of the calculation. The mortality, therefore, resulting from the direct introduction of choleraic dejections in quantities varying from two to six drachms may be set down as amounting to about 43 per cent.

We much regret that the experiments on perfectly fresh choleraic material are not more numerous, a defect which we trust to remedy very shortly. The difficulty has been to procure a suitable animal when an opportunity occurred for resorting to the experiment—to obtain a dog as it is to obtain anything else at the moment wanted being proverbially uncertain.

With this material, one and two days old, five experiments were performed, but all the dogs recovered; whereas when the material used had been kept for three days, three out of four dogs experimented upon died within from three to six hours, and with well-marked lesions in each of them which will be referred to further on. It so happens that in all four of these experiments the same material was used; it was obtained from a questionable case of cholera, and was by no means so offensive to the smell as is generally the case with choleraic dejecta after being kept so long. There are eleven cases recorded in which the choleraic material injected was four days old; of these, six died, or about 54 per cent. In one of the animals which did not die, but was slaughtered, it was found that well-marked intestinal lesions existed. Twelve experiments are likewise cited in which the material used varied from six to twenty-two days old. Four of the dogs died from causes reasonably attributable to the poisonous action of the material introduced, whereas two (puppies) died of shock.

2. Of the seven cases in which the choleraic material injected into the veins had been more or less diluted with water, two died, which will be equal to about 35 per cent., this being considerably lower than the mortality when the undiluted material was resorted to. The *post-mortem* appearances were precisely analogous in both instances, but these will be referred to more at length hereafter.

3. There were twenty-one experiments on the introduction of solutions of ordinary alvine discharges carried out; nine of the animals died, three of these deaths we attribute to shock, which for the sake of uniformity we also leave out of the calculation, thus leaving six deaths, or a mortality a little over 33 per cent., about 2 per cent. less than the mortality from the injection of the diluted choleraic material.

Four experiments are cited in which solution of fowl's blood, filtered and unfiltered, fresh and decomposed, had been introduced into the circulation without producing the slightest result; and one rather remarkable case is given in which fluid obtained from the abdominal cavity of a dog, in whom extreme peritonitis had

recently been induced, and which might be supposed to be highly noxious, produced no appreciable effect; all the organs when examined twenty-four hours after the operation were perfectly healthy.

A Table showing the number of experiments with solutions of normal alvine discharges, the mortality, and the principal lesions induced by their introduction into the veins of dogs.

Age of alvine solutions injected.	Number of Experiments.	Number of Recoveries.	Number of Deaths.	Number in which the *intestines* were affected.	Number in which the *pericardium* was affected.	Number in which the *embolism* was detected.	Remarks.
One day	4	2	2	2	...	...	2 died from shock.
Two days	3	...	3	1	...	...	1 „ „ „
Three „	4	3	1	...	...	1	Pleurisy occurred in one.
Four „	8	5	3	2	...	...	
Five „	1	1	...	...	...	...	
Seven „	1	1	...	...	...	...	
Total	21	12	9	5	...	1	

In carefully looking over the account of the *post-mortem* lesions which occurred in the three preceding classes of experiments, we are struck with the almost constant presence of intestinal complications, varying from more or less intense congestion of the villi and intestinal glands to complete disorganization of the greater portion of the mucous membrane of the small intestine, its epithelial lining becoming completely detached.

With respect to the portion of intestine thus affected, it will be observed that the lesions have been limited to the small intestine and, in the generality of cases, to its whole course from the duodenum downwards, except for a distance of from one to two feet above the ileo-cœcal valve, a portion which in almost every instance has escaped being materially affected. We are totally unable to account for the cause of this exemption, and have tried in vain to reconcile the phenomenon with any known anatomical peculiarities of this part of the gut. We were the more surprised, as we had previously observed, at the autopsies of cholera patients—a subject which we, however, for the present postpone—that it was just this very portion which seemed to show the most marked tendency towards the congestions which every now and then are observed to be present in this disease. Future observation may modify this impression, but we venture to go out of our way a little in order to draw attention

to it. In no instance was any tendency to special affection of the intestinal glands observed. The stomach and the large intestine have in nearly all the cases seemed to us to be quite healthy.

In connection with these observations on the disorganization which the small intestine is subject to, when putrefying matters are injected into the blood, it may be remarked that on three occasions we observed a great number of vibriones or oscillatoria-like filaments, embedded in the mucus which lined the intestine after the substance which was free and filling the lumen of the gut had been wiped away. These may have existed in more numerous instances, and been overlooked; still it may seem strange that they all three occurred in dogs into whose veins the dejection from a very mild or even questionable case of cholera, above referred to, as having proved so fatal, had been injected. We have deemed these occurrences as worthy of attention, more especially when taken in connection with the cases of *mycosis intestinalis*, which, we understand, are prominently alluded to by Professor Parkes in his Annual Review of Hygiene in the recently issued Report of the Army Medical Department, which has however not yet reached Calcutta. We shall certainly continue to watch closely for any organisms of the kind in the intestinal canal of man and of animals. It will be seen that similar actiyely moving vibriones were detected in the mesenteric glands, but not in the blood.

Whilst tabulating the results of the experiments recorded, we were somewhat surprised to observe that when a dog had once recovered from the effects of an operation, succeeding operations had not, in a single instance, proved fatal to it, no matter whether the material introduced into its veins consisted of choleraic or non-choleraic, or of alternate doses of these. One of these animals, a healthy but by no means a very large dog, was subjected to four experiments, a vein in each limb having been injected and tied, without result; another was made use of on three occasions in a similar way, and ten on two occasions, all recovering perfectly. This appears to us to argue very strongly in favour of a predisposition, on the part of animals at all events, to be affected by septic influences.

There were comparatively very few instances in which it could be distinctly noted that marked embolism had occurred; not more than six in sixty-seven experiments. All the dogs, however, were not killed and examined, consequently secondary diseases may have become developed in them afterwards.

4. We have recorded twelve experiments on the effect of injecting the peritoneal cavity with solutions of organic materials of a similar nature to those adopted in the experiments just referred to. Four consisted of choleraic material, three of ordinary alvine discharge, one of a decomposing solution of beef, and four of peritonitic fluid recent and decomposed. Deaths only occurred in three cases, namely, two after the introduction of fluid which had just been obtained from the peritoneal cavity of another dog, and one after the introduction of a solution of decomposing ordinary alvine discharge, the remainder were all killed within twenty-four hours of the

operation, and all, whether they died or were killed, presented the same marked lesion at the autopsy, with two exceptions—one, a dog into whose peritoneum an ounce of fresh peritonitic fluid had been injected without producing any special symptom during life or any lesion evident after death; the other a case in which the injected material consisted of a solution of choleraic discharge.

A Table showing the number of experiments in which decomposing organic solutions were introduced into the peritoneal cavity, the mortality, and the principal lesions produced.

Nature of solution introduced.	Number of Experiments.	Number of Deaths.	Number killed within 24 or 48 hours.	Number in which the *peritoneum* was affected.	Number in which the *pericardium* was affected.	Number in which the *pleura* was affected.	Number in which the *intestines* were affected.
Decomposing beef-tea ...	1	...	1	...	...	...	1
Peritonitic fluid	4	2	2	3	2	...	3
Choleraic dejection ...	4	...	4	4	...	...	3
Normal „	3	1	2	3	1	...	3
Total	12	3	9	10	3	...	10

As in the previous series of experiments with decomposing organic solutions, so in this, the most prominent and constant *post-mortem* phenomenon observed was the affection of the mucous surface of the small intestines. The lesion, however, appeared to us to be of a very different nature; in fact, the mucous membrane itself was not in a single instance materially affected, but a sanguineous exudation had taken place giving the tube of the gut a more or less evenly distributed coating, which, when carefully peeled off with a forceps, left the mucous surface and its epithelial lining intact. This matter was on each occasion very carefully looked into; and the substance exuded, as well as the base upon which it was spread, were subjected to careful microscopic examination. The former consisted, almost entirely, of altered blood elements, blood-crystals, etc., but no entire red corpuscle could be detected, whereas the mucous surface over which it was spread consisted of the unaltered structures belonging to the part.

In two cases in which the intestines were particularly congested, a loop of the gut was tied whilst the animal was still alive but under chloroform, and luke-warm water injected into the ligatured portion in one case, and salt-and-water in the other, the gut in both cases being returned into the abdomen, and chloroform being continued for an hour. When subsequently examined it was found that no absorption had taken place, but the fluid had so macerated the mucous membrane, that the epithelium had

become detached, and floated in flakes in the fluid which had been introduced, and in one of the cases the subjacent mucous membrane had lost all appearance of congestion, whereas it was found to have retained it in the other. In the non-isolated portions of the mucous surface, the small intestine in both instances was intensely injected, otherwise the structure of the membrane was intact.

It may be remarked that in this series of experiments also, a portion of the intestine for a short distance above the ileo-cœcal valve was not materially affected.

In connection with this series it is also to be noted that *Pericarditis*, more or less distinct, was observed in fully one-half of the cases; that portion of the pericardial sac in immediate connection with the diaphragm was the part usually affected, together with the portion immediately attached to the sternum. Perhaps the origin of this may be explained by one of the series of *Observations on the Anatomy of Serous Membranes*, lately published by Drs. Burdon Sanderson and Klein, which shows that when various colouring matters are introduced into the abdominal cavity, the lymphatic vascular system of the diaphragm becomes completely injected, as *also, the sternal vessels and sternal glands.*

The production of *Pericarditis*, but without the coincident occurrence of pleurisy, by the injection of various putrefying substances into the peritoneum, is especially worthy of note, seeing that the opinion is strongly held by many, that, as Lactic acid, when injected in a similar way (as was demonstrated by Dr. B. W. Richardson), produces inflammation of the serous membrane of the heart, this acid must in some way be connected with the phenomena observed in Rheumatism if not in reality its cause. It seems to us that putrefying substances may, on the same grounds, lay claim to a somewhat similar relationship.

With respect to the nature of the fluid produced by the inflammation which had been brought on by the various organic solutions described, it may be observed that under the microscope no difference whatever could be detected between the fluids, beyond that in some cases red blood-corpuscles formed a more prominent feature than in others, but this increased ratio was by no means confined to any particular class of the organic solutions which had been introduced into the abdominal cavity. In the fresh condition this fluid swarmed with irregular masses of bioplasm exhibiting great activity, and very rapidly undergoing the process of segmentation.

When the fluid produced in the peritoneal cavity was transferred to the abdomen of another dog, the bioplastic bodies in the resulting exudation appeared to us to have become smaller and less active: this statement, however, we make reservedly.

With regard to the numbers of bacteria present in this fluid, a fluid, by the way, resulting from the introduction of solutions generally teeming with such organisms, we are convinced that no material increase takes place so long as the inflammatory process is progressing actively. It will be observed, on reference to the experiments bearing on this matter, that in several instances not a single bacterium could be detected

in the recent fluid, and that in all, the numbers present appeared to bear an inverse ratio to the number and activity of the bioplasts.

It will be seen that this series of experiments also failed to induce lesions or phenomena identical in nature with those of cholera; nay more, the affections of the intestine here present, appeared rather to be the result of local disturbance of the circulation excited by the inflammatory action induced by the introduction of extraneous matter into the peritoneal cavity than of the action of any specific agent; in this series likewise, no special action appeared to be excited by choleraic as contrasted with other material. Taken together, the entire series of these preliminary experiments has not afforded any evidence in favour of the existence of a specific poison contained in choleraic excreta, peculiar to them alone, and giving rise to special phenomena when introduced into the system. The number of our experiments do not appear to us to warrant any definite conclusion regarding a difference *in degree* in toxic influence between the two classes of materials; they merely indicate the absence of any special action peculiar to one and absent in the other when introduced into the system by special channels.

It must, however, be evident at first sight that the results obtained from these experiments, have a most important practical bearing on sanitation, seeing that they point most distinctly to the influence of decomposing organic matters in the production of intestinal disease; and show, moreover, that this influence may exist in a most potent form without its presence being in any degree proportionately indicated by the amount of fœtor associated with it.

III.—EXPERIMENTS ON THE SECTION OF THE SPLANCHNIC AND MESENTERIC NERVES.

When we had satisfied ourselves that decomposing organic matters introduced into the circulation exerted the special if not specific actions previously described, on the intestinal mucous membrane, but an action producing lesions materially differing from those characteristic of cholera, we were naturally led to consider the principal points of dissimilarity with a view to ascertain whether future experiments might not be susceptible of any modifications calculated to attain more consonant results.

In doing so, one of the most striking differences, which at once presented itself to observation, one, too, in regard to which there could be no debate, was the almost total absence of any increased secretion of fluid from the mucous membrane, however profoundly the latter might have been otherwise affected.

We had then to consider by what means we might best promote such an increased secretion, so that by combining its employment with the experiments as previously

performed, we might, at all events, assimilate the conditions in the two instances a little more closely to one another. The secretion of fluid might of course have been promoted by the use of drugs or other media introduced into the system, but the complexity of the subject would have been greatly increased by such a mode of procedure, and we therefore decided in the first place to attempt to attain the desired end by means of direct operative interference. It next became necessary to determine in what that interference should consist, and that having been settled, to test with care the effects arising from its influence, when employed alone, before proceeding to combine it with any other experiment.

The best means available and which appeared to warrant a hope of success was section of the intestinal nerves. Moreau's celebrated experiment on section of these nerves showed that the resultant paralysis was accompanied by a copious secretion of watery fluid from the mucous membrane, and it was previously asserted by Pflüger and Nasse that the splanchnic nerves exerted an inhibitory action on the movements of the small intestine, so that there were fair grounds for the selection of such operations with a view to their combination with the experiments on the injection of organic fluids into the circulation.

A.—Section of the Splanchnic Nerves.

Before proceeding to repeat Moreau's experiment, the effects of division of the splanchnic nerves were carefully tested, seeing that it was desirable, if possible, to obtain a means of influencing the whole of the small intestine simultaneously, and not a mere isolated loop or loops as in the procedure adopted by Moreau. The difficulties of such an operation are considerable, and cannot be overcome without some practice, for the situation of the nerves is such that injury to important vessels and viscera is very easily caused, and the abdominal portion of the nerves in the dog is so short as to render it at first a matter of difficulty to distinguish and isolate such small cords as they are. In our experiments the greater splanchnics alone were divided as the lesser nerves are very difficult to secure, due to their small size and to the fact that there is no such definite guide to their position as in the case of the larger nerves. This guide is afforded by the supra-renal capsule. If the outer edge of this body be carefully cleaned, the greater splanchnic may be found with comparative ease, just as it passes beneath it to enter the semilunar ganglion. The main difficulty in the way is a vein of considerable size, which, near the gland, lies close to and almost parallel with the nerve, and which is very liable to be injured in an operation performed in such a narrow space, and affording so many obstructions to the free access of light, as is the angle between the ribs, the diaphragm, and the transverse processes of the vertebræ. Numerous failures first occurred, but eight operations were successfully performed with the results shown in the following statement:—

No.	Nerves divided.	Periods of survival after operation.	Results.
1	Right	A few minutes... ...	No result.
2	Left	1 hour	Mucous membrane dry.
3	„	1 „	„ „ pale and dry.
4	„	1 „	„ „ „ „ „
5	Both	½ „	„ „ „ „ „
6	Left	1 „	„ „ „ „ „
7	Right	9½ „	„ „ „ „ „
8	Both	10 „	„ „ dry.

The following cases have been selected from among these experiments as being the most interesting of them:—

Experiment I (*No.* 5).—A healthy young pariah dog was put under the influence of chloroform, and both splanchnic nerves were divided. The administration of chloroform was then continued for half an hour longer, and the animal subsequently killed. The mucous membrane of the small intestines was not in the least congested; it was, on the contrary, pale and dry-looking, and the cavity of the gut was absolutely devoid of any fluid whatever.

Experiment II (*No.* 7).—A large healthy pariah dog having been put under the influence of chloroform, the right splanchnic nerve was divided. The animal was killed 9½ hours after the operation and a *post-mortem* examination performed at once. The external surface of the intestines was somewhat congested, and there was a little absolute peritonitis in the neighbourhood of the wound, but there was hardly any fluid in the abdominal cavity. Although no evacuations had been passed subsequent to the operation, the intestines were found to be empty, and their mucous surface pale and dry. The bladder was full of urine, secreted since the operation. This was carefully examined, and was found to contain a trace of albumen, but no evidence of the presence of sugar could be detected in it.

Experiment III (*No.* 8).—A healthy pariah dog of average size was put under the influence of chloroform, and both greater splanchnic nerves were divided. Ten hours afterwards chloroform was again administered, and the administration continued until death occurred. An immediate *post-mortem* examination was performed, the abdomen being opened before circulation had ceased. The intestines were pale externally, and the mesentery only here and there showed any evidences of peritonitic action. The intestines were empty, and the mucous membrane dry; in greater part

normal in appearance, but here and there coated with a thin layer of sanguineous exudation.

In all cases careful dissections were made, in order to ascertain without doubt that no mistake existed in regard to the actual division of the nerves. In not a single instance was there the slightest evidence of any increase in the secretion of intestinal fluid; on the contrary, the mucous membrane in the majority of cases was pale and somewhat dry in aspect. In no instance was there any affection of the membrane beyond mere small patches of congestion, or of a thin layer of sanguineous exudation, but not more marked than may frequently be observed in *post-mortem* examinations of healthy animals which have died under the influence of chloroform without having been subjected to any operation, and which, if they were in any degree due to the operations in question, were fairly ascribable to the irritation and tendency to inflammation induced by the opening of the abdominal cavity and the handling of its contents.

Increased activity in the intestinal contractions was in no case observed; but as this was not the subject of immediate inquiry, and as the openings in the abdominal parietes were closed as rapidly as possible on the completion of the operation, it may well have occurred and yet have escaped notice.

B.—Section of the Mesenteric Nerves.

These experiments having failed to achieve the end in view, it was still necessary to repeat Moreau's experiment exactly, as the possibility remained of the semilunar ganglia and solar plexus acting as an independent nervous centre in regulating the secretion of the mucous membrane.

The operation in this case, although in some respects apparently much simpler and more easy of performance than that of section of the splanchnic nerves, is yet beset with difficulties peculiar to itself, and which render great care in its performance necessary. The nerves, as is well known, lie close to the vessels, and are of such small size as to render careful dissection necessary in order to secure their thorough division, and it is in this dissection that the difficulty of the operation lies; for, if the vein be much disturbed, or in any way roughly handled, coagulation of its contents occurs at the isolated portion, and is followed by extreme congestion of the mucous membrane and mesentery, with extravasation between the layers of the latter, and effusion of blood into the cavity of the gut to such an extent as to deprive the observation of all value in regard to the point immediately at issue. Cases of this kind will be given in detail farther on, and the matter is mentioned here only with the view of pointing out that the operation is by no means so simple and easy of performance as might be supposed. The circulation in the portion of gut under operation not unfrequently ceases for a time owing to another cause—the arterial coats when irritated often contract to such a degree as to

occlude the canal of the vessel. This impediment to the circulation is however of no moment as the irritated coats soon relax, and the current of the blood is rapidly restored.

Sixteen experiments of this kind were performed, the results of which are shown in the following statement:—

No.	Nature of operation.	Periods of survival after operation.	Results.
1	Moreau's operation	1 hour ...	No result
2	" "	" " ...	" "
3	" "	" " ...	" "
4	Moreau's operation combined with injection of organic fluid into the veins ...	3 hours ...	" "
5	Moreau's operation	1 hour ...	" "
6	Moreau's operation—2 loops	9½ hours ...	" "
7	Moreau's operation with injection of salt and water into the loop	8½ " ...	Fluid absorbed; loop empty.
8	Moreau's operation	1 hour ...	Vein plugged; deep congestion.
9	" "	9½ hours ...	Loop distended with blood and vein occluded.
10	" "		
11	" "	10 " ...	" " " " " " "
12	Moreau's operation—2 loops	7¼ " ...	General peritonitis; Loop containing a little strawberry-juice fluid.
	(*a*) Injected with water	9 " ...	(*a*) Fluid absorbed—empty.
	(*b*) Not injected		(*b*) Distended with clear serous fluid.
13	Moreau's operation—3 loops		One loop distended with blood, its vein occluded; other loops empty.
14	Moreau's operation—2 loops	10 " ...	
	(*a*) Injected with water	9¼ " ...	Both loops empty.
	(*b*) Not injected		
15	Moreau's operation	9¾ " ...	Contained fluid.
16	" "	8 " ...	Empty; mucous membrane dry.

Before proceeding to give a more detailed account of some of the more remarkable of these cases, and more especially of those exceptional ones in which effusion of fluid really did occur, it may be well to point out a few general facts regarding the entire series. It is remarkable that the animals subjected to operation in no single instance showed any distinct evidences of suffering during the period in which they were allowed to survive the operation. We were naturally averse to keep them alive longer than necessary, and at first only kept them for an hour or two, continuing the administration of chloroform throughout. When, however, such experiments were found only to produce negative results, we were necessarily constrained to prolong life for some time, lest these might have been due to the shortness of the interval elapsing between the operation and death.

Very little peritonitic action was set up in the majority of instances, and in those in which peritonitis did occur to any extent, it was usually ascribable to an extra amount of handling or injury of the viscera incident on some accident in the course of operation, as, for example, on hæmorrhage from the vessels occurring during the separation of the nerves, or on the plugging of the vein with coagulum, and the resultant extreme congestion of the gut and fold of mesentery supplied by it. When general peritonitis had occurred to any extent the mucous membrane of the gut presented patches of mucus of a prune-juice colour such as is ordinarily present in such cases, but these were not localised to the loop, the nerves of which had been divided, nor was there any effusion of fluid into the gut.

The following cases have been selected as affording illustrations of the various phenomena observed as results of the operation :—

EXPERIMENT IV (*No.* 6).—A healthy young pariah dog was put under the influence of choloform, and an incision having been made along the middle line of the abdomen, the cavity was opened and a loop of the small intestine drawn out. The vessels supplying the central portion of this loop were then carefully cleaned, and everything resembling a nervous filament divided. Ligatures were then applied round the intestine at the terminal twigs of the vessels, the accompanying nerves of which had been divided, and finally a loop of intestine on either side was ligatured. The three ligatured loops were now returned to the abdomen, and another portion of the small intestine having been taken out was treated in exactly the same way. The second set of ligatured loops was next returned to the abdomen, and the wound in the parietes carefully stitched up.

The dog rapidly recovered from the influence of the chloroform, showed no indications of pain, and, 9½ hours after the operation, appeared to be quite cheerful in spite of having six loops of its intestines firmly ligatured, two of which, moreover, had their nervous supply divided.

Chloroform was again administered, and continued until death occurred. The abdomen was opened before circulation had ceased, and was found to contain about an ounce of serous fluid, but there were no evidences of general peritonitis. The ligatured loops of intestine were next laid open, but were found in no way to vary from one another, whether their nervous supply had been divided or not. They were all empty, and of a reddish-brown appearance internally, due to sanguineous staining of the normal mucus. This staining extended uninterruptedly from the highest ligatured loop to a little beyond the cœcal extremity of the lowest one. Above the upper ligature, the mucous membrane of the gut was pale and somewhat more moist than in the ligatured loops.

EXPERIMENT V (*No.* 8).—A strong healthy pariah dog was put under the influence of chloroform, and three loops of intestine were ligatured as in the preceding

experiment, the nerves of the central loop being as before divided whilst those of the lateral loops were left intact. The intestine was then returned to the abdomen and the wound sewed up.

After the lapse of an hour the abdomen was again opened, and the ligatured loops were examined. The vein of the central loop had become occluded with coagulum, which had caused extreme congestion of the corresponding portion of the gut, but beyond this congestion no other difference existed between the central and the two lateral loops.

EXPERIMENT VI (*No.* 9).—A large healthy pariah dog was put under the influence of chloroform, and the division of the nerves of a loop of intestine performed in the usual manner.

Nine hours and a half subsequently the animal was killed with chloroform, and the abdomen opened. The ligatured loop, the nerves of which had been divided, was distended like a sausage, and of an intense black colour. There was extreme extravasation along the lines of the vessels in the corresponding portion of mesentery, and the layers of the latter close to the intestine were widely separated by a wedge-shaped mass of tarry blood. The cavity of the gut was distended with black blood, and the tissues of its walls were infiltrated and thickened with similar fluid. This extreme congestion and extravasation had been caused by the complete occlusion of the vein by coagulum at the site of the section of the nerves.

EXPERIMENT VII (*No.* 16).—A small pariah dog was put under the influence of chloroform, and the operation of section of the nerves of a loop of the small intestine performed in the usual way.

After an interval of eight hours, chloroform was again administered until death ensued, and an immediate *post-mortem* examination was then performed.

There was no peritonitis. Not the slightest difference could be detected between the central ligatured loop of intestine in which the nerves had been divided, and the two lateral ones in which they remained intact. The mucous surface was exceptionally dry.

A careful dissection was subsequently made of the portion of mesentery, including the divided nerves, and the division was found to have been almost, if not absolutely, complete.

EXPERIMENT VIII (*No.* 14).—A healthy pariah dog was put under the influence of chloroform, and the nerves of two loops of the small intestine were thoroughly divided. Into one loop (*a*), an ounce of tepid water was then injected, whilst the other loop (*b*) was left empty.

Nine hours and a quarter subsequently the animal was killed, and the intestines were examined at once. The interior of the first loop (*a*) was empty, the mucous

membrane being moist and covered with a layer of soft mucus of a sanguineous hue. The interior of the second loop (*b*) was also empty, but the mucous membrane was in this case dry and much less congested than that of the portions of intestine on either side of the ligatures.

The congested state of the mucous membrane was probably due to the fact that a considerable amount of peritonitis had been caused by the operation.

EXPERIMENT IX (*No.* 12).—A large healthy pariah dog was put under the influence of choloroform, and the two nerve loops of the small intestine were divided in the usual way. Into one loop (*a*) an ounce of water was injected, whilst the other (*b*) was left empty.

Nine hours afterwards the animal was killed, and a *post-mortem* examination was performed at once.

The former loop of intestine (*a*) was empty, and contained merely a little sanguineous mucus, but the latter (*b*) was fully distended with clear serous fluid, containing a few small pale yellowish flocculi. The mucous membrane was soft and of a macerated aspect.

No mistake could have been made as to the identity of the two loops, as they had been carefully distinguished by means of different ligatures, both ends being cut short in one case, whilst one end was left uncut in the other. The flocculi contained in the serous fluid were examined microscopically, and were found to consist of a molecular basis crowded with bioplasts of all sizes, and exactly resembling the flocculi occurring in choleraic dejecta.

Careful dissections of the nerves were made in both cases. In neither were they entirely divided, but the remaining nervous connections were decidedly greater in the second loop (*b*) than in the first (*a*).

EXPERIMENT X (*No.* 15).—A large healthy pariah dog was put under the influence of chloroform, and the nerves of a loop of intestine were divided in the usual way. The animal was killed $9\frac{3}{4}$ hours afterwards, and a *post-mortem* examination was performed at once.

The central loop of intestine contained brownish fluid. The mucous membrane of the two lateral loops was very dry, and was coated with a layer of brownish material identical in colour, and probably in nature with that dissolved in the fluid in the central loop, of which the nerves had been divided. A careful dissection was made of the nerves, and it appeared that, whilst the main trunks had been freely divided, one or two lateral connecting loops of some size remained intact.

The last two cases are peculiarly instructive and noteworthy, inasmuch as they appear to demonstrate a fact which had never previously been experimentally determined, namely, that the relation which the secretion of the small intestines bears to their nervous supply is strictly analogous to that which has long been known

to hold in regard to the secretion of the submaxillary gland and its nervous supply. It was an ascertained fact that partial paralysis of that gland induced hyper-secretion, whilst total paralysis diminished the secretion, but, in as far as we can ascertain, it was a matter of mere conjectural probability that the same held in regard to the small intestines also. The importance of the determination of this point in reference to the pathology of cholera is very great, as it appears to indicate partial paralysis of the intestines as one of the most important lesions in the disease. What the nature of the nervous filaments, which respectively inhibit and promote the intestinal secretion, is, remains undetermined, and is a problem, the solution of which necessarily involves many difficulties, but it is, at all events, a step in the right direction to ascertain that filaments with these different functions actually do exist.

There is another point in connection with the pathology of cholera on which some additional light appears to have been thrown by the above investigations. The increased secretion of intestinal fluid in the disease has been ascribed by some to mechanical obstruction to the current of the capillary circulation, but our experiments appear to indicate that mere obstruction to the circulation causes sanguineous effusion and not hyper-secretion.

Time has not as yet sufficed to allow of any extended series of experiments regarding the effect of division of the nerves combined with injections of organic fluids into the circulation, but we trust that the time expended in following out the above preliminary inquiries may not be deemed to have been wasted, seeing that the latter have afforded some additional information in regard to the action of the cause inducing that series of phenomena which in the aggregate constitute cholera.

We cannot conclude this Report without expressing our own sense of the imperfections under which it labours. Both in the planning and execution of the experiments, we are well aware that there are no small defects, but we trust that in any estimate which may be formed of them, the very many difficulties incidental to such work in India may not be left altogether out of sight.

A REPORT

OF

MICROSCOPICAL AND PHYSIOLOGICAL RESEARCHES

INTO THE

NATURE OF THE AGENT OR AGENTS PRODUCING

CHOLERA.*

(SECOND SERIES.)

BY

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I.—MICROSCOPIC EXAMINATIONS OF BLOOD.

THE question of the microscopic characters presented by the blood in cholera is reverted to in the present report, not because we have to make any material modifications in our former statements, or to record any additional phenomena of any great importance, but as the features previously described as characterising the blood in this disease were by no means such as the views, at present widely prevalent, relative to the causes and methods of diffusion of epidemic disease would have led us to expect, it has been considered advisable to examine the question very carefully again.

Before entering on the discussion of the phenomena of any morbid condition, as we have previously pointed out, it is manifestly requisite that a healthy standard with which they may be compared should be obtained, and if any important deviations from this standard be observed, these again must be compared with those which occur in connection with other diseased conditions. This method of observation has been followed in the present instance, and the results are stated in similar order—the standard phenomena of healthy blood being considered first, those of the disease

* Being one of the Appendices to the Tenth Annual Report of the Sanitary Commissioner with the Government of India, 1874.

specially under investigation next, and finally those of various other (ordinary and artificially induced) diseased conditions.

The methods of examination were precisely the same as those previously employed and described, and consisted in the use of ordinary preparations, preparations which had been exposed to the fumes of osmic acid, and preparations mounted in wax-cells for purposes of continued observation. The microscopic powers employed were the $\frac{1}{8}''$ and $\frac{1}{12}''$ immersion objectives of Ross; and the $\frac{1}{16}''$ and $\frac{1}{25}''$ immersion lenses of Powell and Lealand. We have found the $\frac{1}{16}''$ object glass of the latter makers, and the $\frac{1}{8}''$ of Ross, particularly suitable for investigations of this kind, especially when used *à immersion*.

In connection with the employment of wax-cells in continued observations, renewed experiment was made in regard to their affording the conditions necessary for the development of bacteria or fungal elements, if these were really present. The results agreed with those previously recorded,* preparations of blood inoculated with fluid containing bacteria being quickly decomposed with abundant development of these organisms, and specimens in which one or more of the common atmospheric spores had been enclosed being rapidly dried up by the growth of mycelial filaments, which in many instances produced an abundant crop of their characteristic fructifications. With these preliminary observations we may proceed to a detailed account of our experiments and their results.

A.—Microscopic examinations of the Blood in Health.

The following table shows the characters of eighteen specimens of the blood of healthy subjects, the first fourteen being derived from the human subject, the last four from healthy dogs:—

The features presented in this table, which require special consideration, appear to be the following: the occurrence of echinulation in the red corpuscles, the liberation of granular matter from the white ones, the presence of motile points, fibrinous threads and fungi, and finally, the deceptive appearances due to decomposition of the glasses employed in the preparations.

1. *The echinulation of the red corpuscles.*—This is a phenomenon which has been so long recognized that it would have been unnecessary to notice it here had not considerable stress been laid upon its presence by various recent writers on pathological histology. We find MM. Coze and Felz describing the red corpuscles presenting "l'aspect d'un chaton de marron d'Inde;" and appearing "comme recouverts de piquants qui rappellent très-bien la forme de bâtonnets ou Bactéries," as one

* Eighth Annual Report of the Sanitary Commissioner with the Government of India—Appendix B, p. 154, 1872, and previous pages of this volume.

Ninth Annual Report of the Sanitary Commissioner with the Government of India—Appendix A, pp. 37, 38, 1873, and previous pages of this volume.

of the characteristics of the blood in septicæmia, typhoid, variola, and measles, and suggesting the possibility of such appearances being due to the development upon the red corpuscles of the bacteria which they affirm to be the cause of the diseases in question.*

TABLE I.

Microscopic characters of Normal Blood.

No. of case.	No.	Serum	Red corpuscles.	White corpuscles.	Molecular matter.	Bacteria.	Fungi.	Remarks.
I	1	Clear	Normal ...	Few	None ...	None	None ...	Numerous bacteroid appearances, due to decomposition of cover-glass (*vide* page 143).
„	2	„	„	„	„ ...	„	„ ...	
„	3	„	„	„	„ ...	„	„ ...	
II	4	„	„	„	„ ...	„	„ ...	After some days the white corpuscles discharged their contents and remained as hyaline spheres.
„	5	„	„	„	„ ...	„	„ ...	Inoculated with bacteria, and in 48 hours quite decomposed.
III	6	„	Echinulated	„	„ ...	„	„ ...	This was a very thin layer spread out by pressure on the cover.
„	7	„	Normal ...	„	Sprinkling of motile points	„	„ ...	Numerous glass bacteria; no pressure applied.
IV	8	„	Echinulated on pressure	„	Very few ...	„	„ ...	Echinulation produced and increased at will by pressure.
V	9	„	Normal ...	„	Sprinkling ...	„	„ ...	Echinulation appearing on pressure; numerous delicate fibrinous threads in the serous spaces.
„	10	„	„	„	„ ...	„	„ ...	Ditto ditto ditto.
VI	11	„	„	„	None ...	„	After 3 days.	
„	12	„	„	„	„ ...	„	None ...	No fungi appeared in this at any time.
VII	13	„	„	„	Sprinkling ...	„	„ ...	Blood from the heart of a dog.
VIII	14	„	„	„	Very few ...	„	„ ...	„ „ „ „ „ „
IX	15	„	„	„	None ...	„	„ ...	Blood from the liver of a dog.
„	16	„	„	„	„ ...	„	„ ...	
„	17	„	Echinulated	„	„ ...	„	„ ...	
X	18	„	Normal ...	„	„ ...	„	„ ...	
X	18	...	...	...	6	...	1	

It is no doubt true that a phenomenon like that of echinulation may be induced by various causes, and that some of these causes may be morbid conditions of the

* "Récherches cliniques et expérimentales sur les maladies infectieuses étudiées spécialement au point de vue de l'état du sang et de la présence des ferments."—Paris, J. B. Baillière et Fils, 1872. p. 76.

blood; still there is very great need of caution in interpreting the significance of any phenomena which we find may co-exist with health in the subjects furnishing the specimens under examination, nay more, which may be induced accidentally or at will by slight modifications in manipulation. Now, we have no hesitation in affirming that this is the case in regard to the phenomenon under consideration, and, although at first inclined to ascribe some importance to its presence, we have in the course of experience come to regard the whole matter with grave suspicion. Numerous experiments clearly showed that echinulation was the invariable consequence of employing a very small quantity of blood so as to spread it out in a very thin layer (*vide* No. 6, Table I), or of pressure wilfully applied to thick layers (*vide* Nos. 8 and 9 of the same table).

That other influences beyond mere mechanical pressure do, however, result in producing similar appearances was clearly manifest in one or two cases in which the phenomenon came on gradually in specimens preserved in wax-cells in which there could certainly be no pressure on the corpuscles, beyond that of the contained air; nor could the evaporation have been sufficient to have accounted for the alteration. However induced, the condition appeared in one of two forms: to the first of these, in which the corpuscles appeared beset with very fine projecting points, the term "echinulation" is strictly applicable: whilst in the other "tuberculation" more accurately represents the condition, for the corpuscles, instead of presenting their normal smooth outline, were covered with obtuse projections of various sizes. Both forms were commonly present in one and the same sample, although one or other usually predominated.

2. *The liberation of granular and molecular matter from the white corpuscles.*—This process, occurring almost invariably in specimens of blood subjected to continued observation, was fully described in the previous report, and we now again call attention to it merely in order to reiterate the statement that such granules and molecules might very easily be supposed to be extraneous particles of bacteroid nature, were not their source and process of liberation clearly demonstrated by continuous observation of individual specimens.

3. *Motile particles.*—It will be seen that these were observed in six samples of blood from five cases, and when present they formed a characteristic feature. They were excessively minute solitary points, just visible under the highest powers employed, and in incessant active motion in the serous spaces among the corpuscles. They were present in the blood immediately on its removal from the body, underwent no further development in specimens retained under observation, but on the contrary usually disappeared within a short time. Their nature could not be satisfactorily determined, but they certainly showed no evidence of being organized, and their motion, although very energetic, may very probably have been purely mechanical,

as particles of such excessive minuteness must naturally tend to move actively for some time, when the fluid containing them is subject to so much disturbance as is involved in procuring and mounting specimens of it for examination. The chief point of importance in regard to them is, that bodies of such a nature may occasionally be detected in the blood of individuals apparently in perfect health.

4. *Fibrinous threads.*—In two of the specimens of the table, delicate fibrinous threads were numerous, crossing the serous spaces between the corpuscles. We have observed that threads of this nature very soon disappear, and in these particular preparations they were not visible after an interval of twenty-four hours.

5. *Bacteria.*—Distinct bacteria were observed in no instance either as actually present in the specimens immediately on their removal from the body, or as being developed in them during the time in which they were retained under observation —a time varying from a few days to several months.

6. *Fungi.*—In only one instance were fungi developed in a specimen whilst under observation; but, as the forms which were developed in this instance were those belonging to ordinary atmospheric spores, and as only one of two specimens simultaneously obtained from the same individual was affected, the presumption is that they were due merely to accidental contamination, and not to the presence of any inherent fungal elements in the blood.

7. *Phenomena dependent on imperfections in the glass of slides and covers.*—It will be seen that in four specimens numerous bacteroid bodies were present, which were traced to imperfections in the surface of the glasses employed to mount the specimens. It may appear unnecessary to enter into any detailed discussion of such appearances, but as we were for a considerable time somewhat misled by such appearances, and as it seems very probable that other observers, on whose observations great reliance has been placed, have been similarly misled, we consider that a brief account of such fallacious appearances—which we propose to call "spectral bacteria"—may not be amiss.

In describing preparations of blood and of choleraic fluids in previous reports reference has more than once been made to the appearance of "milky spots," * and it was in working with such specimens that the phenomena due to slight erosions of glass surfaces in contact with viscid fluids were first clearly recognized. It was casually observed that the cover-glass in a particular specimen, which showed these milk spots in considerable numbers, had been slightly affected with that form of surface decomposition which so rapidly renders thin glass useless for microscopic work

* Ninth Annual Sanitary Report, App. A, p. 26.

in this country, ultimately converting it into a whitish translucent medium like ground glass. Attention having been attracted to this as a possible explanation of the previously unaccountable "milk spots," numerous experiments were tried with glasses affected in various degrees with surface erosions, and a great variety of extremely deceptive appearances were traced to the existence of such a condition either in the cover-glasses or in the slides employed. When the erosions were comparatively large, they gave rise to appearances simulating cellules of various sizes; whilst when every minute, spectral molecules, monads and bacteria were produced. Some of the bacteroid markings were peculiarly deceptive, consisting of oblong or rod-like appearances separated from one another by what seemed to be joints. All these spectral cellules, microzymes and bacteria are of course motionless, although a slight movement may sometimes *appear* to occur, due to imperceptible changes in the position of bodies, such as blood corpuscles, in the preparation affected.

These appearances are to be recognized in one or other of two positions in the preparation, coming into focus either before, which is much more common, or after the real solid bodies contained in the fluid. For example, in a preparation of blood they are either found immediately beneath the cover-glass, coming into view before the red corpuscles are defined, or more rarely at the bottom of the preparation after the corpuscles have lost their sharpness of outline. When present in small numbers only, they are frequently exceedingly deceptive, more especially those of the upper layer, when, as is sometimes the case, they are interspersed among real solid particles; but there is one infallible means of distinguishing them, for all such spectra first make their appearance as *shaded bodies, becoming bright as the focus is deepened*, often, more especially when of some size, assuming a pinkish tinge whilst doing so, *and passing out of view as bright spaces.* Now, as these phenomena are just the reverse of those occurring in the case of actual solid particles, such as bacteria, which appear *first as bright points* becoming *shaded on deepening the focus*, they may always be distinguished by a little careful examination, but at the same time they easily deceive if a preparation be but cursorily examined. Such appearances are, very probably, much less liable to be met with in other climates where glass surfaces are not so prone to decomposition, but the possibility of their occurrence should always be borne in mind.

This idea particularly suggests itself in connection with the importance which MM. Coze and Felz attach to the occurrence of a "zone immobile" of bacteria, in specimens of blood in various infectious diseases. These authors say in reference to this point:—"Dans cet examen microscopique, une circonstance nous a frappés, et nous n'avons trouvé le fait consigné nulle part. En tournant la vis du microscope pour mettre l'instrument au point, on aperçoit comme un semis de corpuscles tout à fait immobiles et assez rapprochés les uns des autres. Le semis paraît tantôt, et le plus souvent, fixé a la partie interne de la plaque recouvrante, tantôt, plus rarement, à la plaque inférieure, * * * cette zone a été également signalée tout récemment

par Davaine." The appearance of this "zone immobile," agrees very closely with that due to glass erosions, and it is manifest that the latter might very easily be mistaken for or confounded with organic particles.

8. As regards the alleged constant presence of sarcinæ or their elements in the blood, we have only to repeat our former statement that our observations (and this applies as well to morbid as to healthy specimens) have not afforded it the slightest confirmation, so that, in so far as this country at all events is concerned, it appears to be wholly unfounded.

B.—Microscopic examinations of the Blood in Cholera.

The following table shows the results of the examinations of forty-one specimens of blood from twenty-two cases of cholera :—

TABLE II.

Microscopic characters of Choleraic Blood.

No. of case.	No.	Serum.	Red corpuscles.	White corpuscles.	Bacteria.	Fungi.	Remarks.
I	1	Clear, abundant	Normal ...	Very abundant	None ...	None... ...	
,,	2	,,	,,	,,	,,	,,	
,,	3	,,	,,	Few	,,	,,	
II	4	,,	,,	Very abundant	,,	,,	
III	5	,,	Echinulate ...	,,	One or two after 3 days	,,	
,,	6	,,	Normal ...	,,	None ...	,,	
IV	7	,,	,,	,,	,,	,,	
,,	8	,,	,,	,,	,,	,,	
V	9	,,	,,	,,	,,	,,	
,,	10	,,	,,	,,	,,	,,	
VI	11	,,	Very diffluent	,,	,,	After 8 days	Delicate fibrinous threads in the serous spaces.
VII	12	,,	Normal ...	Abundant ...	,,	,,	
VIII	13	,,	,,	Normal ...	,,	,,	Patient not in collapse ; attack very slight.
,,	14	,,	,,	,,	,,	,,	Fibrinous threads present.
IX	15	,,	Diffluent ...	Abundant ...	,,	,,	,, ,,
,,	16	,,	,,	,,	,,	,,	
X	17	,,	Normal ...	,,	,,	,,	
,,	18	,,	,,	,,	,,	,,	
,,	19	,,	,,	,,	,,	,,	Fibrinous threads present.
XI	20	,,	,,	,,	,,	,,	,, ,,
,,	21	,,	,,	,,	,,	After 15 days	,, ,,
XII	22	,,	Diffluent ...	,,	,,	,,	
,,	23	,,	,,	,,	,,	,,	Fibrinous threads present.
XIII	24	,,	,,	,,	,,	,,	,, ,,
,,	25	,,	,,	,,	,,	,,	Common preparation.
XIV	26	,,	Very diffluent	Sprinkling ...	,,	,,	Wax-cell preparation.
,,	27	,,	Diffluent ...	Abundant ...	,,	,,	
XV	28	,,	,,	Sprinkling ...	,,	,,	
,,	29	,,	,,	,,	,,	,,	
XVI	30	,,	,,	Abundant ...	,,	,,	Fibrinous threads present.
,,	31	,,	,,	,,	,,	,,	
XVII	32	,,	Very diffluent	Very abundant	,,	,,	,, ,,
,,	33	,,	,,	,,	,,	,,	
,,	34	,,	,,	,,	,,	,,	
XVIII	35	,,	Diffluent ...	Abundant ...	,,	,,	Fibrinous threads present.
,,	36	,,	,,	,,	,,	,,	,, ,,
XIX	37	,,	Normal ...	Normal ...	,,	,,	
XX	38	,,	,,	Abundant ...	,,	,,	Fibrinous threads present.
,,	39	,,	,,	,,	,,	,,	,, ,,
XXI	40	,,	Very diffluent	Sprinkling ...	,,	,,	
XXII	41	,,	Diffluent ...	Abundant ...	,,	,,	

It will be seen that the results here recorded are almost identical with those of the former report; showing the same absence of bacteria, fungi, or other extraneous bodies; and the same general prevalence of considerable leucocytosis. There is one phenomenon, however, prominently noted in this instance which was not adverted to previously, and that is the diffluent condition of the red corpuscles. This was observed in no less than twenty instances, the condition being very strongly pronounced in four of these. It showed itself in a tendency manifested by the corpuscles to aggregate in irregular masses in place of forming the normal rouleaux;* and, in ordinary preparations where any pressure was exerted, and in which there was any movement of the fluid, in the ease with which the corpuscles altered their forms, were drawn out into irregular processes or adhered to one another by elastic protrusions. Fine fibrinous filaments were observed in the serous spaces in fourteen preparations, disappearing as the clot contracted, and the corpuscles became closely aggregated to one another. A "zone immobile" of spectral bacteria was present in four cases, and bacteria and fungi made their appearance after intervals of some days in four others.

In place of repeating the general statements contained in the previous report regarding the phenomena observed in specimens of choleraic blood in general, it may be well here to introduce a detailed account of those occurring in an individual characteristic case in which observations were carried on for some time.

Three specimens of blood were obtained three hours before death from a patient, pulseless, in profound collapse, and with a rectal temperature of 105° F. The blood was very dark-coloured and appeared abnormally thick. Of the three specimens one (*a*) consisted of an ordinary preparation destined for immediate examination, whilst the other two (*b* and *c*) were mounted in wax-cells for continued observation. The first specimen (*a*) was examined at once. The red corpuscles were aggregated in irregular masses, appeared very diffluent, and showed very little tendency to form rouleaux. Leucocytes were present in extreme abundance and in a state of great activity. In some of the serous spaces an appearance of a meshwork of very delicate threads was visible, due to the presence of filaments of a fibrinous nature in some cases; to fine processes connected with active leucocytes in others; and to fallacious appearances due to the presence of very tenuous, ill-defined leucocytes, the contained molecules of which, coming out more distinctly into view than the investing protoplasm, appeared as though free in the surrounding fluid. Not a trace of bacteria or of vibriones could be made out.

The two other preparations were not examined for twenty-two hours. At the close of that period both presented similar features, so that one description is sufficient for them. The serum was abundant and quite clear, forming a wide zone around the

* This phenomenon has been observed by MM. Coze and Felz in the blood in septicæmia, typhoid, variola and measles (op. cit. pp. 76, 148, 196, 242), and by Davaine in that in charbon (Comptes Rendus, T. LVII, p. 351, August 10th, 1863.

small clot occupying the centre of the preparation. The red corpuscles were well preserved and were irregularly massed together. White corpuscles were present in extreme abundance, their numbers being so great as to cause the formation of a white fringe along the edge of the clot visible to the naked eye, whilst under the microscope very many fields were entirely occupied by masses of them. Very few of the corpuscles now retained any movement or showed any changes in form, and the majority were circular, finely molecular, and contained a variable number of refringent granules. Twenty-four hours later—forty-six from the date at which they were obtained—but little change had occurred in either specimen. The white corpuscles had become more or less distinctly vacuolated and all movement had ceased; the red corpuscles were well preserved and the serum was abundant, quite clear and free of any traces of bacteria or vibriones. The preparations were examined at intervals. Five days after the last examination the changes in the leucocytes had advanced considerably, increased vacuolation being visible in some, whilst in others the granular mass of the bioplast protruded more or less from one or other side of a large clear vacuole; in some the two bodies were almost entirely separate, whilst in others total separation had been completed and the granular mass exhibited various stages of disintegration—a process which resulted in the appearance of free granules and molecules and small patches of such particles throughout the serum.

After this, although the preparations were retained under observation for a month longer, the only further changes observed in them were increasing disintegration of the white corpuscles, loss of distinctness in the outlines of the red corpuscles, and a change of their colour to a bright rosy hue, accompanied by a certain amount of staining of the serum. The preparation remained fluid throughout the entire period of observation, but no development of any unequivocal bacteria or vibriones ever occurred. There was of course ultimately a generally-diffused sprinkling of granules and molecules derived from the breaking-up of the leucocytes, but neither by form, growth, nor motion did they show themselves to be truly bacterial in their nature.

This case presented almost all the characteristic features of choleraic blood, the only one which was not observed being the swarming movement of the contents of the white corpuscles; but as the preparations, after the first day or two, were only examined at intervals, the phenomenon was very probably present, although the precise time of its occurrence did not coincide with that at which any examination took place.

As in all our previous examinations not the faintest trace of evidence presented itself in favour of the presence of any bacteria or other foreign organisms or germs in the blood in cholera—all the phenomena observed were ascribable to alterations, relative or absolute, in the normal elements of the blood, not to the presence of any new or extraneous bodies of such nature as to be detected by microscopical research.

We have now examined numerous specimens of blood derived from cases of every degree of severity and at every stage of the disease during life and shortly after death,

and, had the presence of foreign organisms in the blood been essentially related to the disease in one way or other, whether as causes of the diseased condition or as indications of its existence, it is scarcely conceivable that they should have consistently failed to afford the slightest evidence of their presence. We are all well aware that these statements are likely to be received with some incredulity by a very large number of the members of the medical profession, made as they are at a time when views regarding the important and almost necessary influence of "germs," "bacteria," "microzymes," etc., in the development of epidemic disease are so widely diffused and so much quoted; but, in bringing our examinations of the blood from this point of view to a close, we feel bound to state our results and conclusions distinctly.

C.—Microscopic examinations of the Blood in Diseases other than Cholera.

In considering questions connected with the blood in cholera, more especially in reference to the doctrines referred to at the close of the previous section, it was important to determine whether the blood in diseased conditions beyond all doubt capable of direct communication by inoculation, differed from that in cholera in any important respect, more especially whether it necessarily contained distinct organisms of any kind recognisable by the use of the microscope. After some deliberation vaccinia was selected as the most convenient for this purpose, as there is no objection to the production of the condition in the human subject and a definite series of observations at known periods from the introduction of the morbid agent into the system can be carried out.*

The table on the next page shows the results of the examination of forty-seven specimens of blood derived from five cases in which vaccination had been performed:—

The specimens, as shown in the table, dated from twenty-four hours up to nine days subsequent to vaccination. Of the five cases, No. I was abortive, no vesicles ever making their appearance. Nos. II and III were moderately successful, whilst No. IV, and No. V, which was vaccinated directly from it, were excellent cases with large well developed vesicles. The most prominent respect in which these specimens of blood differed from those in cholera was in the absence of any appreciable leucocytosis; the only specimens in which the white corpuscles were in excess belonging to case II, the subject of which was in an anæmic condition, due to influences of climate, and habitually showed an abundance of leucocytes in the blood.

In seventeen of the forty-seven specimens motile particles were observed. These were of extreme minuteness, appearing as barely perceptible points, with a rotating or jerking movement in the inter-corpuscular spaces. They showed no evidences of being organisms. Their movements were not more active than those in other instances, certainly

* There is another advantage attending the selection of vaccinia; the disease whilst running a definite course is not of a fatal or dangerous nature, and therefore phenomena due to impending death of the organism, or of any of its parts are not likely to occur, *vide infra* p. 165.

due to mechanical action. These particles were as abundant in the abortive case as in any of the others, and were least abundant in the two successful ones, none being present in the specimens from one and very few in those from the other of these; and, as they have been already mentioned as occurring in specimens of blood obtained from healthy individuals, they do not appear to demand further consideration here.

TABLE III.

Microscopic characters of Vaccinial Blood.

Case.	No.	Serum.	Red corpuscles.	White corpuscles.	Molecular matter.	Bacteria.	Fungi.	Remarks.
I	1	Clear	Some echinulated	Very few	None	None	None	24 hours after vaccination.
,,	2	,,	Normal	Normal	,,	,,	,,	,, ,, ,, ,,
,,	3	,,	,,	,,	,,	,,	,,	,, ,, ,, ,,
,,	4	,,	,,	,,	Sprinkling, motile	,,	,,	32 ,, ,, ,, Abundant fibrinous threads.
,,	5	,,	,,	,,	Very few particles	,,	,,	48 ,, ,, ,,
,,	6	,,	,,	,,	Abundant	,,	,,	56 ,, ,, ,,
,,	7	,,	Some echinulated	,,	,,	,,	,,	,, ,, ,, ,,
,,	8	,,	Normal	,,	None	,,	,,	72 ,, ,, ,,
,,	9	,,	Some echinulated	,,	,,	,,	,,	104 ,, ,, ,, Some bioplastic fragments.
,,	10	,,	Normal	,,	,,	,,	,,	144 ,, ,, ,,
,,	11	,,	,,	,,	,,	,,	,,	9 days ,, ,, ,, ,,
,,	12	,,	,,	,,	One or two particles	,,	,,	9 days 6 hours ,,
II	1	,,	,,	,,	Sprinkling	,,	,,	24 hours after ,,
,,	2	,,	,,	,,	Abundant	,,	After 72 hours	,, ,, ,, ,,
,,	3	,,	,,	,,	None	,,	None	24 ,, ,, ,,
,,	4	,,	,,	,,	,,	,,	,,	32 ,, ,, ,, Bioplasts distended and crowded with moving particles.
,,	5	,,	Many broken up	,,	Abundant	,,	,,	48 ,, ,, ,,
,,	6	,,	Normal	,,	,,	,,	,,	,, ,, ,, ,,
,,	7	,,	,,	,,	None	,,	,,	72 ,, ,, ,,
,,	8	,,	,,	,,	,,	,,	,,	96 ,, ,, ,,
,,	9	,,	,,	,,	,,	,,	,,	104 ,, ,, ,,
,,	10	,,	,,	,,	Sprinkling	,,	,,	128 ,, ,, ,,
,,	11	,,	,,	,,	,,	,,	,,	9 days ,, ,,
III	1	,,	,,	Abundant	Abundant	,,	,,	72 hours ,, ,,
,,	2	,,	,,	,,	,,	,,	After 7 days	,, ,, ,, ,,
,,	3	,,	,,	,,	A sprinkling	,,	,,	,, ,, ,, ,,
,,	4	,,	,,	,,	,,	,,	,,	,, ,, ,, ,,
IV	1	,,	Somewhat diffluent	Normal	None	,,	,,	8 days ,, ,,
,,	2	,,	Echinulated	,,	,,	,,	,,	,, ,, ,, ,, A very thin layer.
,,	3	,,	Normal	,,	,,	,,	,,	,, ,, ,, ,,
V	1	,,	,,	,,	Sprinkling	,,	,,	48 hours ,, ,,
,,	2	,,	,,	,,	,,	,,	,,	,, ,, ,, ,,
,,	3	,,	,,	,,	None	,,	,,	120 ,, ,, ,,
,,	4	,,	,,	,,	,,	,,	,,	,, ,, ,, ,,
,,	5	,,	,,	,,	,,	,,	,,	144 ,, ,, ,,
,,	6	,,	,,	,,	,,	,,	,,	158 ,, ,, ,, Abundant fibrinous threads.
,,	7	,,	,,	,,	,,	,,	,,	,, ,, ,, ,, Bioplasts very active.
V	37	37	...	...	17	...	2	

Distinct bacteria were absent throughout the whole series, and although fungi occurred in three instances, they were not developed until after uncertain intervals, did not belong to the same species in the several instances, and were not confined to the same case, so that their extraneous origin was evident.

Specimens of blood from cases of syphilis were next examined, but in these also no foreign organisms could be detected. It was thus manifest that as the blood in these

two undoubtedly inoculable diseases (into which a multiplication of the poison within the system takes place) showed no evidence of the presence of organised ferments,* it is not to be wondered at that we have found it impossible to say from microscopic examination of the blood whether cholera should be classed with those few diseases which are known to be inoculable or with those which are not.

Having failed to detect the presence of bacteria or their germs as an essential feature in the blood of an epidemic disease (cholera) and of two undoubtedly contagious and inoculable ones (vaccinia and syphilis), the next question that suggested itself was, under what circumstances are such bodies to be found in the blood; careful examinations were, accordingly, made of the blood, in the course of numerous and varied experiments on animals, and the following were the results.

The experiments in question have been arranged in separate tables, according to the nature of the procedure employed in the various instances; and a final table is given showing the cases in which bacteria were present in the blood, the nature of the experiment, and any points of interest which the cases presented.

TABLE IV.

Microscopical characters of the blood in cases in which Choleraic materials were injected into Veins.

Case.	Specimen.	Character of fluid injected.	Bacteria in blood at varying periods after operation.
I	1	Fresh choleraic evacuation	None.
"	2	" " "	"
"	3	" " "	"
II	4	" " "	"
"	5	" " "	"
III	6	" " "	"
"	7	" " "	"
IV	8	" " "	"
V	9	Fresh boiled choleraic evacuation	"
VI	10	Fresh strained choleraic evacuation	"
VII	11	Fresh boiled and strained choleraic evacuation ...	"
VIII	12	" " " " " ...	"
"	13	" " " " " ...	"
IX	14	Fresh strained choleraic evacuation	"
X	15	Fresh boiled and strained choleraic evacuation ...	"
XI	16	Fresh strained choleraic evacuation	"
XII	17	Fresh boiled and strained choleraic evacuation ...	"
XII	17	... ...	——

* "The proof that virus which has no organisation may be contagious in infinitesimal quantities, may be found in the transmission of syphilitic virus. Try to calculate the relation between the proportion of virus which has communicated syphilis to a man, and the proportion of virus from the mucous surface of the throat of the same individual which proves sufficient to transmit the disease to another person. Or estimate the quantity of virus contained in the spermatozooid of a syphilitic individual, a quantity sufficient to produce the disease in the mother and to infect the ovum fecundated by the spermatozooid. In all such cases, if we cannot exactly conceive how an albuminoid substance transmits its alteration to another organism, this is not a reason for admitting special phenomena in these cases, and an infection by multiplication of microscopic beings."—(M. Onimus.) A *resumé* of a critical analysis of views on septicæmia in the *Moniteur Scientifique-Quesnevill* (October) by A. B. MacDowall:—London Medical Record, November 1873, p. 722.

TABLE V.

Microscopic characters of the blood in cases in which Non-Choleraic Organic fluids were injected into Veins.

Case.	Specimen.	Nature of fluid injected.	Bacteria in blood at varying periods after operation.
I	1	Peritonitic fluid	None.
,,	2	,, ,, ...	,,
II	3	Blood	,,
,,	4	,, ...	,,
III	5	Solution of healthy fæces	A sprinkling of active bacteria.
IV	6	Strained solution of healthy fæces	None.
,,	7	,, ,, ,, ,, ...	,,
V	8	Boiled and strained solution of healthy fæces ...	,,
,,	9	,, ,, ,, ,, ,, ...	,,
VI	10	Strained solution of healthy fæces	,,
VII	11	Boiled and strained solution of healthy fæces ...	,,
VII	11		Bacteria present in one.

TABLE VI.

Microscopic characters of the blood in cases in which Peritonitic fluid was injected into the Peritoneal cavity.

Case.	Specimen.	Nature of fluid injected.	Bacteria in blood at varying periods after operation.
I	1	Peritonitic fluid	None.
,,	2	,, ,, ...	,,
II	3	,, ,, ...	Three bacteria observed.
,,	4	,, ,, ...	None.
III	5	,, ,, ...	,,
IV	6	,, ,, ...	,, *
V	7	,, ,, ...	,,
,,	8	,, ,, ...	,,
VI	9	,, ,, ...	,,
VII	10	,, ,, ...	,,
,,	11	,, ,, ...	,,
VII	11		One.

* Some bodies appeared in this, which were at first taken for large bacteria, but which turned out to be crystals.

TABLE VII.

Microscopic characters of the blood in cases in which Organic matters were injected into the Peritoneal cavity.

Case.	Specimen.	Nature of fluid injected.	Bacteria in blood at varying periods after operation.
I	1	Urine and tinctura iodi	None.
,,	2	,, ,, ,, ...	One or two bacteria observed.
II	3	Solution of healthy fæces...	None.
,,	4	,, ,, ,, ...	,,
III	5	,, ,, ,, ...	,,
,,	6	,, ,, ,, ...	,,
IV	7	,, ,, ,, ...	,,
IV	7		One.

TABLE VIII.

Microscopic characters of the blood in cases in which purely Chemical irritants were injected into the Peritoneal cavity.

Case.	Specimen.	Nature of fluid injected.	Bacteria in blood at varying periods after operation.
I	1	Tinctura iodi and water	One or two.*
,,	2	,, ,, ,, ...	None.
II	3	Liquor ammoniæ	Abundant, active.
III	4	Tinctura ferri perchloridi	None.
,,	5	,, ,, ,, ...	,,
IV	6	,, ,, ,, ...	,,
V	7	,, ,, ,, and water	,,
,,	8	,, ,, ,, ,, ...	,,
VI	9	,, ,, ,, ...	,,
,,	10	,, ,, ,, ...	,,
VI	10		Two.

* This specimen was obtained from a small vein, rendering chances of accidental contamination greater than usual.

TABLE IX.

Microscopic characters of the blood in cases in which HEALTHY *animals were killed* WITHOUT *previous experiment.*

Case.	Specimen.	Temperature (Fahr.).		Kind of death.	Bacteria in the blood at death, and up to 48 hours subsequently.
I	1		73° 9′	Killed under chloroform; examined at once ...	None.
„	2		„	Ditto ditto	„
„	3		„	Ditto ditto	„
II	4		71° 9′	Ditto ditto	„
III	5		85° 5′	Ditto ditto 8 hours afterwards...	Abundant, active.
IV	6		86° 3′	Ditto ditto 8 „ ...	„ „ still (blood from veins).
„	7		„	Ditto ditto 8 „ ...	None (blood from left side of heart).
V	8		69° 6′	Ditto ditto 12 „ ...	A sprinkling of bacteria.
VI	9		73° 1′	Ditto ditto 24 „ ...	None.
VII	10		72° 8′	Ditto ditto 24 „ ...	Abundant.
„	11		„	Ditto ditto 24 „ ...	„
VIII	12		68° 0′	Ditto ditto 24 „ ...	A sprinkling.
„	13		„	Ditto ditto 24 „ ...	Very abundant.
IX	14		67° 6′	Ditto ditto 24 „ ...	A few.
„	15		„	Ditto ditto 24 „ ...	None.
X	16	69° 4′	69° 1′	Ditto ditto 48 „ ...	Abundant.
XI	17	67° 3′	63° 9′	Ditto ditto 48 „ ...	None.
XI	17				Nine.

TABLE X.

A Summary of all the cases in which Bacteria were present in the blood.

Case.	Specimen.	Nature of case.	Bacteria in blood at varying periods after death.
I	1	Injection of healthy feculence into the veins ...	A sprinkling of bacteria; 5½ hours after death.
II	2	Injection of peritonitic fluid into the peritoneal cavity.	Three bacteria observed immediately after death.
III	3	Injection of urine and tinctura iodi into the peritoneal cavity.	One or two bacteria observed immediately after death.
IV	4	Injection of liquor ammoniæ into the peritoneal cavity.	Abundant bacteria observed immediately after death.
V	5	Injection of tinctura iodi and water into the peritoneal cavity.	One or two bacteria observed immediately after death.
VI	6	Healthy dog killed by chloroform	Abundant after 8 hours.
VII	7	„ „	„ „ „ „
VIII	8	„ „	A sprinkling „ 12 „
IX	9	„ „	Abundant „ 24 „
„	10	„ „	„ „ „ „
X	11	„ „	A sprinkling „ „ „
„	12	„ „	Very abundant „ „ „
XI	13	„ „	A few „ „ „
XII	14	„ „	Abundant „ 48 „

The above tables show that of seventy-three specimens of blood derived from forty-seven different animals, fourteen, or somewhat over 19 per cent., contained bacteria in smaller or larger numbers; that the presence of bacteria was not the result of any special experimental treatment; and that bacteria may be found in specimens of blood obtained from the bodies of animals killed while in full health, and without having been subject to any operative interference previously. The animals were in every instance dogs, so that the question of idiosyncrasy in hindering or promoting the development of bacteria, can be so far set aside when the results of any one set of cases are compared with those of the others.* Of the fourteen specimens ten were obtained from the bodies of animals at periods varying from 5½ to 48 hours after death, and only four from cases in which the animals had been killed immediately before the examination, and in which changes dependent on *post-mortem* decomposition could not be supposed to have played any important part in the production of peculiarities in the blood. Table X shows the length of time which elapsed in each instance between the death of the animals and the time at which the specimens of blood were obtained, and brings out the fact very distinctly that, in so far as the whole of the present experiments are concerned, it was this that almost invariably determined the existence of bacteria in the blood. In three of the four instances in which bacteria were found in the blood immediately after the death of the animal the numbers present were so very small as to fail to constitute a characteristic of the blood or escape the suspicion of accidental introduction.

In one specimen (No. 3, Table VIII), however, obtained immediately after death, bacteria were present in abundance; and in another (No. 5, Table V), in which their numbers were considerable, death had occurred at such a short time previously (5½ hours) that it may not be deemed warrantable to conclude that all the bodies present had really been developed subsequent to the death of the animal. That it would really be an unwarrantable conclusion is, however, very doubtful, as two of the experiments in healthy dogs show that, with the high temperature of the hot months, a development of bacteria may take place within a very few hours in the blood of animals into the system of which such bodies had been previously artificially introduced. In the case under discussion the body was exposed to the hottest part of the twenty-four hours of a day towards the close of May. Even, however, if it be assumed, that the bacteria were certainly in this case not due to *post-mortem* processes, their appearance in the blood can be readily explained without supposing that they exerted any essential influence on the death of the animal, for, as death followed within three hours after the injection of several drachms of fluid containing an abundance of bacteria, it may well have happened that all those introduced had not been destroyed ere death occurred, and that, on its occurrence, the medium and temperature being favourable, they rapidly developed and multiplied.

* In the blood of rabbits, for example, bacteria are said to be much more readily developed than in the blood of other animals.

In the experiments in which healthy animals were employed, the procedure consisted in administering chloroform until death ensued, and then laying the bodies aside on a shelf without further interference. The results do not manifest that freedom of the healthy tissues and fluids from the elements of bacteria which is maintained by some of our most distinguished observers. That such a freedom should exist is certainly not supported by the analogy of processes which may be observed in healthy vegetable cells, and there is much reason to suspect that the observations on which the doctrine has been founded have been too limited and too little varied to allow of valid generalisations being drawn from them. This especially would appear to be the case in regard to conditions of temperature, for it is manifestly impossible to lay down a general law in regard to such developments, from observations carried on under one set of conditions only. In order that future experiments on this point may be compared with those now given, a column has been added to Table IX, showing the mean temperatures of the days on which these experiments were conducted.

Only one case remains demanding any special notice, namely, that of specimen No. 3, Table VIII, in which active bacteria were present in abundance in the blood immediately after death. The animal from which the specimen was obtained was in a state of extreme depression, and evidently dying when chloroform was administered to it, and the chief point of interest lies in the fact that the morbid condition had in this instance not been induced by the introduction of any organic fluid, or of any fluid which might be supposed to contain bacteria or their germs, but was due to the intense and destructive inflammation resulting from the injection of liquor ammoniæ into the peritoneal cavity.

This case is a parallel of those described by Dr. Burdon Sanderson in his researches into infective inflammation, in which inflammatory fluids of a highly infective nature,—a nature which is, according to that experimenter, characterized by the presence of bacteria in the effused fluids,—resulted from the introduction of pure chemical media destructive of bacterial organisms, or which had been previously subjected to boiling;—cases in which, whatever part the organisms in the fluid play in regard to its infectious nature, there could be no doubt as to the manufacture of that fluid with all its infectious properties within the living organism by a process of self-infection.

In the former report on experiments on animals, the occurrence of peculiar elongated vibriones in the mesenteric glands, in cases in which death had resulted on injection of choleraic fluids into the circulation, was recorded, and our attention was again attracted to the subject by observing similar organisms in several of the specimens of blood obtained from healthy animals at intervals after death. Renewed examinations of the gland fluid and of the mucous membrane of the small intestines under similar circumstances were accordingly undertaken.

The table given on next page shows the results of the examinations of the contents of the mesenteric glands:—

TABLE XI.

Examination of fluid from Mesenteric Glands at varying periods after death.

Case.	No.	Nature of Case.	Period of examination after death.	Bacteria and other Organisms.
I	1	Healthy dog	Immediate	None.
II	2	Ditto	Ditto	Ditto.
III	3	Ditto	24 hours	Abundant.
IV	4	Dog; abdomen opened and splanchnic nerves irritated 24 hours before	Immediate	None.
V	5	Healthy dog	Ditto	Ditto.
	6	Ditto; portion of gland having been ligatured and excised	72 hours	A few.
	7	Ditto; portion of gland having been ligatured, excised, and immersed in melted wax	72 „	Ditto.
VI	8	Healthy dog	24 „	Abundant.
VII	9	Ditto	16 „	Ditto.
VIII	10	Ditto	48 „	Ditto.
IX	11	Ditto	24 „	Very few.
X	12	Ditto	24 „	None.
XI	13	Ditto	48 „	Abundant.
XII	14	Ditto	Immediate	None.
XIII	15	Man who died of cholera	6½ hours	Ditto.
XIV	16	Healthy dog	Immediate	Ditto.
	17	Ditto; gland fluid preserved in wax-cell	24 hours	Ditto.
XV	18	Dog; killed 4 days after injection of choleraic fluid into veins	Immediate	Ditto.
XVI	19	Dog; died after injection of choleraic fluid into veins ...	1 hour	Ditto.
XVII	20	Dog; died 3 hours after injection of healthy alvine discharge into veins	5½ hours	A few.
XVIII	21	Healthy dog	8 „	Abundant.
XIX	22	Ditto	8 „	A sprinkling.
XX	23	Dog; died 8 hours after injection of choleraic fluid into veins	1½ „	None.
XXI	24	Man; died of cholera	5 „	Ditto.
XXII	25	Dog; killed 48 hours after injection of choleraic matter into veins	Immediate	Ditto.
XXIII	26	Dog; killed 48 hours after injection of boiled choleraic matter into veins	Ditto	Ditto.
XXIV	27	Dog; killed 24 hours after injection of healthy alvine discharges	Ditto	Ditto.
XXV	28	Dog; died after injection of boiled healthy alvine discharges	Some hours	Ditto.
XXVI	29	Dog; killed 24 hours after injection of choleraic fluid ...	Immediate	Ditto.
XXVII	30	Ditto 48 ditto ditto ditto ...	Ditto	Ditto.
XXVIII	31	Ditto 48 ditto ditto ditto ...	Ditto	Ditto.
XXIX	32	Ditto 24 ditto ditto of healthy alvine discharges	Ditto	Ditto.
XXX	33	Ditto 24 ditto ditto ditto	Ditto	Ditto.
XXXI	34	Dog; died 12 hours after injection of fresh choleraic fluid	12 hours	A sprinkling.
XXXII	35	Dog; died after injection of peritonitic fluid into peritoneal cavity	Some hours	Abundant.
XXXIII	36	Dog; died after injection of peritonitic fluid into peritoneal cavity	A few hours	A few.
XXXIV	37	Ditto ditto	10 hours	Abundant.
XXXV	38	Ditto ditto	12 „	Ditto.
XXXVI	39	Ditto ditto	Some hours	Ditto.
XXXVII	40	Dog; killed 24 hours after injection of peritonitic fluid into peritoneal cavity	Immediate	None.
	40			Present in 17 cases.

This table hardly requires comment, as the results speak for themselves.

In seventeen of the forty specimens, bacteria were present in the contents of the glands, but these were *derived from healthy dogs* in no less than ten instances; and the *only* feature common to all the cases in which bacteria and allied organisms were present, was that a certain interval of shorter or longer duration had elapsed between death and the examination of the glands.

The results afforded by an examination of the mucous membrane of the intestinal tract were naturally not so uniform and well defined as those regarding the contents of the glands. That membrane is exposed to portions of undigested and disintegrating materials which are constantly more or less liable to contain bacterial elements and to contaminate with these any specimens obtained from the surface with which they are in contact. Nevertheless, even here important indications of the rapidity with which *post-mortem* changes may give rise to remarkable phenomena were not wanting on investigation. Although on immediate examination of the mucous membrane few bacteria and none of the large serpentine vibriones (previously described as occurring in preparations of the blood and the contents of the glands) were to be found, yet, when a period had elapsed between the death of the animal and the examination of the body, the extent to which such organisms had developed and invaded the tissues was most remarkable. This condition, as in the previous cases, occurred without reference to the cause of death—no matter, whether the animal had died owing to the introduction of organic fluids into the system or had been killed whilst in perfect health.

The two following cases are selected as examples of the phenomena present in such cases, and of the coincidence of the occurrence of a development of vibriones in the mucous membrane of the small intestines, in the interior of the mesenteric glands, and, in one of the cases, in the blood:—

Case I.—A powerful healthy pariah dog was killed by means of chloroform at 8 A.M. of December 1st, 1873, and the body laid aside for twenty-four hours. At the close of that period a *post-mortem* examination was performed, and the temperature having been comparatively low (73°·1 F.) decomposition was not at all advanced in so far as the unaided senses could determine. Microscopic preparations were obtained from various viscera, and were immediately examined with the following results:—

1. *Reddish fluid from the sac of the pericardium.*—No red blood-corpuscles could be found in this, but numerous elongated, motionless, vibrionic filaments were present, in some cases showing one or more distinct joints.

2. *Blood from the heart.*—This was firmly coagulated. It contained an abundance of large crystals, and the red corpuscles were in great part disintegrated, but no *distinct* bacteria or vibriones were to be found in it.

3. *Fluid from the interior of the mesenteric glands.*—The cut surface of the gland was of a dull, dirty pinkish hue. The fluid was full of molecular *débris* and oily granules. It contained, in addition, numerous staves, thick, jointed, and in some instances exhibiting characteristic active movements.

4. *A scraping from the clean surface of the mucous membrane of the small in-*

testine.—This was almost entirely composed of a mass of bacteroid staves of all sizes; some undivided, others segmented, and all motionless.

CASE II.—A healthy dog was killed, as in the former case, and set aside for forty-eight hours, from the morning of the 20th to that of the 22nd of December, 1873. Specimens of blood from the heart, of fluid from the mesenteric glands, and of the surface of the mucous membrane of the small intestines, were then procured and examined with the following results:—

1. *Blood.*—The red corpuscles were well preserved. The white corpuscles were distended into hyaline spheres, with their contained granules aggregated into one or more distinct masses. Throughout the serum there were numerous free particles in active mechanical movement, and a sprinkling of large, elongated bacteria and vibriones divided into two or more segments, and in some cases showing characteristic movements.

2. *Fluid from the interior of the mesenteric glands.*—This was crowded with molecular matter and oily granules, and contained an abundance of long, active vibriones, swimming to and fro with an undulating flexion, dependent on bending both at their component joints and in the course of the individual segments.

3. *Mucous membrane of the small intestines.*—Scrapings from this were full of flakes formed of epithelium, stained yellow by the colouring matter of the bile. Between these flakes there was a thick felted mass composed of large bacteria, and of elongated, jointed vibrionic bodies like those in the contents of the glands, and showing the same undulating movement as the latter, whenever they had room and freedom to do so.

In other cases, a similar development of vibriones was found to have occurred beneath layers of exudation or in the deeper strata of the epithelial coat of the intestine, and the appearances were such as might readily have been supposed to indicate the existence of severe lesions dependent on parasitic invasion of the tissues by vegetable organisms, had they not been found to occur in healthy subjects as well, and to be dependent on *post-mortem* changes and developments.

Even those who believe in the general freedom of the healthy tissues and fluids from the elements of vegetable organisms, allow that the intestinal mucous membrane does not participate in this freedom, and it would hardly have been necessary to enter upon the question of the phenomena dependent on the rapid *post-mortem* development of such organisms there, had it not been for the prominence that has been given to phenomena, which are, at all events, very similar to these, occurring in the so-called "*mycosis intestinalis.*"* That such developments take place *post-mortem* in

* In regard to this, see "The London Medical Record, 1874," containing an abstract from the "Berliner Klinische Wochenschrift," of Fränkel and Orth, on two cases of Malignant Pustule in the adult. The points of chief interest, from the present point of view, regarding these cases, are: (*1st*), that in one case the *post-mortem* examination did not take place until the second day after death; and (*2nd*), that the blood of the second case examined a few hours before death, and when the patient was collapsed and cyanotic, afforded only negative results, although examined under high powers and with immersion lenses; while on *post-mortem* examination an abundance of bacteria were discovered in it.

some cases, is, of course, no evidence that they always do so, or that they cannot occur during life and give rise to injurious or fatal results; but the fact is one which requires to be prominently brought forward, and to be carefully borne in mind in the investigation of all such obscure etiological subjects.

In our former report we drew special attention to these phenomena and gave a minute description with figures of the objects referred to; but as we have since, on more than one occasion, observed statements to the effect that organisms (beyond any reasonable doubt identical in their nature with these) had been detected after death in this or in that disease, and conclusions drawn as to the significance of their presence which are more conducive to the retardation than to the advance of our knowledge of the true pathology of these diseases, we again give a woodcut of the principal forms presented by these *post-mortem* developments, as seen under a $\frac{1}{16}$ of an inch immersion objective.

It is difficult to give these bodies one name which shall embrace all the forms.

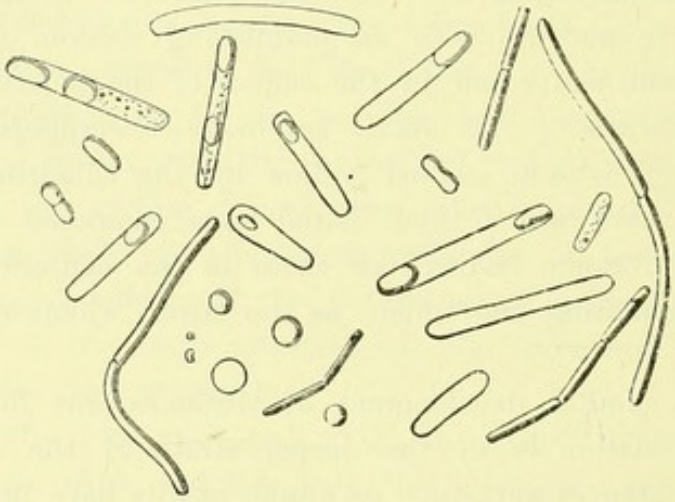

Fig. 4. × 1500.

Organisms found in the tissues of *healthy* animals a few hours after death.

Some are long and jointed, extending in a few cases almost across the field of the microscope, reminding us of the *Bacillus subtilis* figured in Cohn's "Memoir on Bacteria;" * others are more like *Vibrio rugula* and *Vibrio serpens:* whilst intermixed are innumerable bacteria of various forms and sizes; some with vacuoles at one end, others showing them at both ends or towards the middle, with here and there circular cells containing oily molecules not unlike Cohn's *Saccharomyces glutinis* in appearance. After being kept for a day or two, the activity of the vibriones, etc., diminishes or ceases altogether, and eventually the staves break up into oil-like beads held together by a soft, hyaline material.

We have frequently found these in the blood and in all the organs of the body of healthy animals within twelve hours after death, and considerably sooner when the temperature was unusually high. On the last occasion when we undertook the

* *Vide* Quarterly Journal of Microscopical Science, Vol. XIII, new Series, 1873, page 156.

examination of a healthy dog specially with the object of elucidating this matter, we found that the spleen was particularly affected; there was a regular network of *Bacillus* or *Vibrio*-like rods throughout the substance of the organ. This appearance very naturally suggested to us that the presence of "Bacteridia" in "malignant pustule" and "the blood," so frequently brought forward in support of the theory of the causation of disease by vegetable organisms, may after all be more a consequence than a cause; a suggestion which receives support from the fact that Cohn refers these particular "Bacteridia" to the genus *Bacillus*.

In all our experiments and statements we have rigidly confined the use of the terms bacteria and vibriones to bodies which, either by form, motion, or development, have distinctly shown that they really were true bacteria of one form or other, and have refrained from classing minute particles, granules, and molecules of undetermined nature along with them. Many authors use the word "microzymes" to include a heterogeneous mass of minute bodies, organic and inorganic, living and dead;* in fact, any molecular or granular particles to be found in fresh or decomposing fluids or tissues; and many statements and theories regarding the production of disease are founded on such arbitrary classification and vague nomenclature—

> "human pride
> Is skilful to invent most serious names
> To hide its ignorance."

Moreover, the terms microzymes and bacteria are very commonly employed, as though they were equivalent; whereas the one is a name invented to suit certain theoretical views, whilst the other is a definite term employed in classification to include certain low vegetable organisms; hence it is evident that if all minute particles of matter, even if only of organic and living matter, are to be called microzymes, and that term then used and understood as equivalent to bacteria, great confusion must be induced.† Dr. Beale has pointed this out very clearly when arguing in favour of his views regarding the nature of "disease germs," but the confusion still prevails, and owing to its existence and to the vague use of terms, it is very difficult to estimate the value of many of the statements at present adduced as evidence of the existence of bacteria in morbid fluids and tissues.

There appears to be a tendency to assume on very insufficient grounds that such organisms are necessarily the causes of all diseases of an epidemic or communicable character, and, consequently, to recognize as vegetable parasites all minute particles of an undetermined nature occurring in the fluids and tissues in such diseases; but,

* According to Béchamp, all the "granulations moléculaires" visible in animal and vegetable tissues are "microzymes," or germs capable of evolving bacteria. Such bodies are, according to him, constantly present in the blood of animals, the fibrine being merely a false membrane formed of microzymes, the life of which is not destroyed by an exposure to the influence of boiling with water, as is proved, in his opinion, by their subsequent development into bacteria, and action as ferments when submitted to suitable conditions.—Comptes Rendus, Tomes LX, LXVIII, LXIX.

† On this point *vide* Dr. Burdon-Sanderson's remarks at the British Association, 1873.

as Dr. Bastian has ably pointed out, that such an etiology must necessarily be found for these diseases, or has been distinctly demonstrated for any of them is by no means the case.* This comes out very clearly when, even in regard to septicæmia, a disease for which a vegetable origin has been accepted more generally, perhaps, than for any other, we find that an authority like Dr. Burdon-Sanderson refuses to allow that anything beyond a coincidence has been proved to exist between the occurrence of bacteria and the presence of infective properties in inflammatory fluids,† and that observers, such as Robin,‡ Stricker,§ and Billroth,¶ fail to detect such bodies in the blood of *living* animals suffering from the disease.

Our own experience has not been favourable to the acceptance of any such doctrines regarding the influence of bacteria and allied organisms, nor can we accept them until much more evidence than at present exists has been adduced in their favour. We feel that all evidence founded on *post-mortem* examinations, however remarkable the phenomena in such cases may be, requires most cautious scrutiny; for, even if it be granted that the normal tissues and fluids do not, as a rule, contain the elements of bacteria and remain free of such organisms for prolonged periods under peculiar circumstances, these circumstances, as our experiments show, are certainly not those to which dead bodies are ordinarily exposed.

In regard to this particular point, questions relative to the ultimate origin of the bacteria are not of special moment. It matters little whether their presence be due to entrance from without, to the development of inherent germs, or to heterogenetic transformations in the elements of the fluids and tissues; the really important fact being that, in one way or other, they are capable of appearing in healthy as well as in morbid materials. Even were vegetable organisms of a distinct nature demonstrated to exist in the dead fluids and tissues of each disease, the fact might merely indicate the existence of peculiarities in the composition of the medium, and additional evidence in favour of their causative relations to the antecedent disease processes would yet be necessary.

Where the presence of such organisms is demonstrated during the life of the host, the case is no doubt different; but even here, there is a great lack of evidence to prove that they really are causes and not consequences of the diseased condition. Dr. Burdon-Sanderson's experiments prove the development of infective inflammatory products as the result of the introduction of pure chemical irritants, and we ourselves have found bacteria in the blood of an animal dying from such an experiment, and yet it cannot be maintained that the bacteria present in such cases were the causes of the diseased condition.

* Appendix E, "The Beginnings of Life."
† *The Lancet*, Vol. I, 1873, p. 734.
‡ "*Traité Du Microscope*," Paris, 1871, p. 932.
§ The *Medical Times and Gazette*, Vol. I, 1873, p. 62.
¶ The *Medical Times and Gazette*, Vol. II, 1874, p. 48.

Moreover, other evidence is in existence directly opposed to the necessary agency of vegetable organisms or, more correctly, of living matter of any kind, as the effective agent in the production of diseases of this nature; for Stricker* and Panum† find that boiling does not affect the virus of septicæmia, whilst Davaine states that neither boiling nor rapid desiccation affect that of *Charbon*.‡ Our own observations on this particular point will be found narrated further on (pages 175, 176, 182).

There is one point in regard to this question which appears to be worthy of more attention than it has as yet generally met with, and this is, that in very many of the diseases to which a vegetable origin is assigned, the blood affords evidence of considerable leucocytosis. Now, in as far as our observations go, such a process is incompatible with the simultaneous development of bacteria in the same specimen of blood; we have, indeed, on a former occasion, whilst referring to a similar subject, expressed the opinion that "the numbers present appeared to bear an inverse ratio to the number and activity of the bioplasts.§" Bacteria on being introduced into the circulation rapidly disappear from the blood unless death ensues, and all the phenomena appear to indicate that, so long as the leucocytes are in a state of activity, the former are worsted in the struggle for existence. Only when the activity and multiplication of the leucocytes cease, and coincident with the occurrence of disintegrative changes in their substance, do bacterial elements begin to appear and multiply. At this time, however, their development may be very rapid, and appear more rapid than it really is, owing to the difficulty of distinguishing between the granular *débris*—the "granulations moléculaires"—of the leucocytes, and the elements of the independent organisms. A process in which living leucocytes are attacked and destroyed by bacteria has, however, in so far as we know, not yet been observed, far less has one in which the presence of bacteria first induces leucocytosis and then destroys the resulting cells.

Most of the diseases which have been ascribed to bacterial agency are very severe and frequently fatal in their nature, and herein a possible source of fallacy is involved. In cases in which a fatal termination is rapidly impending, partial death affecting the elements of fluids and tissues to a greater or less degree may precede general death of the organism—the sum of the deaths of its constituent elements—and in such cases changes usually observed after the death of the organism, may take place in such fluids and tissues; so that, even in cases in which bacteria are found in the blood or other fluids *ante-mortem*, they may merely be the results of the advanced degree of the diseased condition, not the causes of its development.

This may probably be the explanation of the phenomena observed in inflammatory fluids and in the blood in cases, such as those already more than once referred to, in

* The *Medical Times and Gazette*, Vol. I, 1873, p. 62.

† Virchow's Archiv, 1862.

‡ Comptes Rendus, T. LVII, page 351, August 10th, 1863.

§ Appendix C, page 197, Eighth Annual Report of Sanitary Commissioner, 1872.

which the diseased condition was demonstrably due to chemical agency, as well as of many others in which similar phenomena may occur.

It is possible that all the diseases ascribed to vegetable parasites may in reality be due to the influence of such organisms, but the proof of it has yet to be produced, and it is no real advance to ascribe them to such an origin on insufficient ground. This theory has attractions for many, on account of the apparently simple explanation which, if true, it would afford of the multiplication of disease-poisons. But, even allowing that such a multiplication could only take place under the influence of living matter and not as the result of any mere chemical process, it must always be borne in mind that the manufacture of the poison must, in any case, occur under the influence of multitudes of living cells and particles, cells and particles which may be just as capable of elaborating such poisons as vegetable organisms or other living matter introduced from without.

II.—ADDITIONAL EXPERIMENTS ON THE INTRODUCTION OF CHOLERAIC AND OTHER ORGANIC FLUIDS INTO THE SYSTEM.

As so much of the evidence placed on record relating to the existence of a specific virus in choleraic discharges has been based upon experiments which have been conducted on lower animals, it was resolved that the opportunities for repeating such experiments which Calcutta affords should be sedulously utilised in order, if possible, to settle the question for once and for all. The fact that the animals usually subjected to experiments of this kind have been of a very fragile constitution, accounts for a considerable amount of the discrepancy which exists between the statements made as to the effects of various septic influences upon them and the conclusions derived from these effects by various observers. In relation to the same question, and that from every-day experience indeed, we have no hesitation in saying that the inferences which have been deduced from experiments on septic poison conducted on such animals as rabbits, mice, and guinea-pigs, are untrustworthy in the highest degree.* That implicit reliance, however, is, very generally, placed upon the result of experiments obtained by feeding delicate animals with choleraic discharges is evident from some of the statements contained in the Report which has just been issued by the Vienna Cholera Conference. In one place it is mentioned that "les expériences

* In reference to similar experiments and conclusions regarding *Charbon*, M. Sanson remarks: "Je craindrais de trop forcer les analogies en concluant des petits rongeurs aux ruminants, et je ne crois pas me tromper en disant que la cause des dissidences que se produisent sur la question est dans cette consideration."—Comptes Rendus, Tome LXVIII, page 341.

de M. Thiersch à Munich ont prouvé que de petits morceaux de papier imbibés dans les selles des cholériques étaient capables de produire les formes du choléra." We ourselves attempted carrying out a series of observations on such animals, but found the results so hopelessly contradictory that we determined on resorting to others of more robust constitution, even though in many ways they might not be so manageable.*

We have already recorded a considerable number of such experiments, and trust that the evidence deducible from them and those now about to be referred to will be deemed sufficient to settle at all events some of the points so strongly debated at present in connection with the causation of disease.

We have in this, as in the former series of observations, selected the pariah dog as the most suitable and readily attainable animal, and need scarcely add that the precautions then taken not to inflict unnecessary pain have been strictly adhered to; anæsthetics being administered whenever any experiment which could prove painful had to be undertaken, and the animals kept under their influence as long as the experiments lasted. Such of the animals as it was deemed necessary to destroy were invariably placed under the influence of chloroform and not permitted to awaken, so that they certainly met with their death in a less painful manner than would otherwise have been their fate; for, sooner or later, they would have fallen into the hands of the men employed in diminishing the number of the dogs prowling about the streets.

Having on a former occasion given somewhat fully the details of numerous experiments, we do not deem it necessary again to repeat in detail for each case the various steps which were taken, but shall describe the experiments in as concise a manner as possible, as the copious notes which have been accumulated, although of value to ourselves in forming an opinion as to the lesson which each observation conveys, would only be tedious to the reader, and unnecessarily add to the length of our report.

In our summaries of each group of experiments we shall include the data already published, and thus epitomise the results of all the experiments bearing on this subject which we have conducted—results based on careful and more or less prolonged observations of the effects produced by septic agents on some two hundred animals, forming, if we be not mistaken, a more extended series than any yet recorded, and certainly one conducted upon a greater number of animals likely to yield more trustworthy data.

* That it is not without some show of reason that we place but little confidence in the results of experiments with such delicate animals is evident from the following remarks by Professor Parkes, in his Report on Hygiene for 1873, which has reached us since this paper was in the press. Dr. Parkes states, in reference to the very experiments cited at the Vienna Conference, that Professor H. Ranke of Munich had found that filtering paper *unsoiled* with the discharges produced injurious effects on mice.—Army Medical Report, Vol. XIV, 1874, page 253.

A.—Experiments on the injection of Choleraic and other Organic fluids into the Veins of animals.

In continuing this set of experiments, we had the following objects in view:—

1*st.*—To supply a deficiency in our last report, for which at that time we expressed our regret, *viz.*, "that the experiments on perfectly fresh choleraic material were not more numerous."

2*nd.*—To confirm or modify our inference that the observations then recorded did not afford "any evidence in favour of the existence of a specific poison contained in choleraic excreta, peculiar to them alone, and giving rise to special phenomena when introduced into the system."

3*rd.*—To accumulate a sufficient number of such experiments as to warrant our drawing something like definite conclusions as to the difference in *degree* between the toxic influence of choleraic as distinguished from normal alvine discharges.

4*th.*—To test to the utmost the influence of bacteria in these processes. The questions regarding the influence of bacteria on disease, as well as those relative to the origin of such organisms, have been referred to by an able writer as directly facing us, and as likely to hamper us in the course of further inquiries until disposed of.* In so far as the morbid processes specially considered in the present report are concerned, we trust that the question regarding the influence of bacteria in the causation of disease has been satisfactorily determined, and we believe that the allied question as to whether or not the introduction into the system of *living* bodies of *any* kind is necessary for the production of the particular morbid phenomena under consideration, is also disposed of. With regard, however, to the ultimate origin of bacteria, we have not yet been able from our own observation to come to any final conclusion.

5*th.*—Lastly, to ascertain whether the product resulting from lesions thus produced invariably possesses the property of reproducing the phenomena in a more marked or even equal degree.

These questions will be severally referred to after the narration of the experiments, as it will be more convenient to discuss them when the data upon which the conclusions are based are fully expressed and tabulated:—

1.—Experiments on the introduction of **NORMAL** alvine solutions into the veins of dogs.

We have somewhat reversed the arrangement of our tables on this occasion, so as to be able at starting to show what the result of introducing solutions of ordinary excrementitious substances into the circulation is, and to ascertain approximately the average proportion of definite results to be obtained from such a proceeding, before referring to the effects of similar material obtained from choleraic patients.

It will be seen that we have added eight observations to the four recorded in our

* *British Medical Journal*, 14th February, 1874, page 208.

previous report, in which perfectly fresh solutions of alvine discharges had been prepared. Of these eight, one died; but of the four previously recorded, not one. Consequently, the mortality from the introduction of such a material (excluding of course such accidents as embolism, etc.) may be referred to as averaging about 8 per cent. The mortality resulting from the introduction of putrid material is, however, as we have previously shown, considerably higher; for out of seventeen animals thus treated, six died apparently from the toxic influence of the solution introduced: thus yielding a mortality of something like 35 per cent.—the period most fatal being when the material was from three to four days old.

TABLE XII.

(*a*)—*The material introduced being* Fresh *and Not subjected to* Heat.

Experiment No.	Vein selected.		Quantity injected.	Affected.	Remarks.
	Femoral.	Saphena.			
I	1	...	Two drachms ...	...	The temperature did not exceed 102° F.
II	1	...	Four drachms ...	...	Urine highly coloured on the second day, sp. gr. 1020; no albumen. On the third day temperature = 103°; on the 4th 103°; on the 5th 103°; the sp. gr. of urine on the last day being 1035; no albumen; no sugar. Before the experiment was commenced the temperature of this dog was 104° F. in the rectum.*
III	1	...	Five drachms ...		
IV	1	...	Four drachms ...	1	The dog died in three hours, but no special *post-mortem* lesions could be detected.
V	1	...	Four drachms ...		
VI	1	...	Six drachms ...	...	*Post-mortem* examination showed mesenteric glands somewhat affected, but nothing further.†
VII	...	1	Seven drachms ...	...	This dog had been subjected to a similar experiment previously.
VIII	...	1	Seven drachms ...		
Total... 8	6	2	... ...	1	

Showing, however, the fallacy of being entirely guided by averages in matters of this nature, and apparently exemplifying the idiosyncrasies of animals in their susceptibility to septic influences, are the facts that the mortality resulting from the introduction of *boiled* solutions of fresh alvine discharges was greater than was yielded when the same material was unboiled, and that the same fluid in some cases produced a result, but in others did not. This appears to be the interpretation of the results shown in the table given on the next page:—

* With reference to the high temperature frequently recorded in apparently healthy dogs, it should be borne in mind that this is probably owing to the high temperature of the fermenting fæcal matter in the rectum—the rectum should therefore, when possible, not be selected for the application of the thermometer.

† The result of subsequent microscopical examinations of the organs and tissues of this and of other animals are referred to under separate headings.

TABLE XIII.

(b)—The material introduced being Fresh, *but subjected to* Heat.

Experiment No.	Vein selected.		Temperature.		Number of drachms injected	Affected.	Remarks.
	Femoral.	Saphena.	Degree.	Duration.			
IX	1	...	212°	3 minutes	Four	...	Continued depressed for a couple of days, but otherwise showed no symptom of illness.
X	1	...	212°	3 minutes	Four	1	The dog died during the night, having passed copious, sanguineous, liquid evacuations. The intestines were coated with a sanguineous exudation.
XI	1	...	212°	3 minutes	Six		
XII	...	1	212°	3 minutes	...	1	Vomited frequently during the day, and was greatly purged. Died in 8 hours. Mucous surface of intestine extremely congested. The evacuations exhaled a fishy, mawkish, choleraic odour.
XIII	...	1	212°	3 minutes	Six	...	This dog appeared to be in no way affected, although the material used was from the same vessel, and the experiment performed at the same time as the dog in Exp. XII.
XIV	...	1	212°	3 minutes	Six	...	The animal used in Exp. V (Table XII) again subjected to similar treatment. No result.
XV	...	1	212°	5 minutes	Five		
XVI	...	1	212°	3 minutes	Seven		
XVII	...	1	212°	3 minutes	Four		
Total... 9	3	6	...	... ..	...	2	

TABLE XIV.

(c)—The alvine solution introduced having become Putred: Heated *shortly before use.*

Experiment No.	Vein selected.		Temperature.		Number of drachms injected.	Affected.	Remarks.
	Femoral.	Saphena.	Degree.	Duration.			
XVIII	...	1	212°	3 minutes	Six	...	This dog had been subjected to somewhat similar treatment previously, without result.
XIX	...	1	212°	3 minutes	Four	1	Died within 12 hours. The same fluid used as in Exp. XVIII, the principal *post-mortem* lesion appeared to be embolisms in the lungs.
XX	...	1	212°	3 minutes	Four	...	The same fluid as in Exp. XVIII and XIX, Table XIV.
XXI	..	1	212°	4 minutes	Seven	...	Ditto ditto ditto.
Total ... 4	...	4	...	...	...	1	

With reference to the effect of boiling on the toxic properties of alvine discharges, nothing very conclusive can be inferred from the observations summarised in the two foregoing tables. It is important, however, to observe that the intestinal canal in at least two of the animals experimented upon was seriously affected, in consequence of the introduction of *boiled* alvine discharge from a healthy person.

The probable influence exerted by heat on such substances will be subsequently referred to; meantime it may be stated that, to the extent applied in the foregoing experiments, it certainly does not appear to diminish or modify their toxic properties.

2.—Experiments on the introduction of **choleraic** alvine discharges into the blood of dogs.

The want of a sufficient number of experiments on perfectly fresh choleraic excreta which we have previously referred to as occurring in our last report—an omission regarding which more than one distinguished writer has expressed his regret—will, we trust, be considered as satisfactorily made good by the publication of the following account of twenty-three experiments on as many dogs. In ten of the experiments the material injected into the blood was simply strained, and in thirteen the fluid was first subjected to heat, then allowed to cool and strained before being employed. A tabulated statement of the first-mentioned class of experiments is annexed:—

TABLE XV.

(a)—The Choleraic material introduced being Fresh *and Not subjected to* Heat.

Experiment No.	Vein selected.		Number of drachms injected.	Affected.	Remarks.
	Femoral.	Saphena.			
XXII	1	...	Four	1	The material injected consisted of almost colourless watery fluid. Death resulted in 5 hours, without marked intestinal symptoms. Although the *post-mortem* examination was conducted within 2 hours after death, the stomach and intestines were enormously distended with gas: the intestinal glands could be seen very distinctly through the distended walls of the gut. The mucous surface was disorganized, and presented all the characters of acute septic enteritis; lungs collapsed; the splanchnic nerves and semilunar ganglia apparently unaffected.
XXIII	1	...	Four	...	Temperature at the time of the operation 102° in the vagina. Next day 104° in rectum, but 102° in vagina: appeared unaffected till the fourth day, when it was killed under chloroform. All the viscera were healthy. The bladder full of urine (sp. gr. 1012), and the intestinal contents quite normal.
XXIV	1	...	Four	1	The fluid injected was nearly colourless (sp. gr. 1004), and contained a few red blood-corpuscles. The dog died in about 18 hours. The intestines presented the appearance usual in gastro-enteritis. The blood was crowded with crystals, but not a trace of bacteria could be detected.

TABLE XV (*continued*).

(*a*)—*The Choleraic material introduced being* Fresh *and Not subjected to* Heat.

Experiment No.	Vein selected.		Number of drachms injected.	Affected.	Remarks.
	Femoral.	Saphena.			
XXV	1	...	Two	...	On the second day the temperature was 104°5, on the 3rd 103°, on the 4th 104°, when the animal died. There were no special *post-mortem* appearances, except in the liver, where numerous minute embolic patches were visible and considerable softening. Death evidently due to embolism.
XXVI	1	...	Four	1	Death in 7 hours.
XXVII	1	...	Four	1	Death in 6 hours. The same material used as in Exp. XXVI.
XXVIII	1	...	Four	1	Death within seven hours. The animal had not been purged, but the intestinal mucous membrane was much congested and softened.
XXIX	1	...	Four	...	Watched for 3 days; killed under chloroform; the intestines were found to be quite healthy.
XXX	1	...	Four	...	The dog escaped on the second day, apparently in excellent health.
XXXI	1	...	Four	...	Ditto ditto ditto.
XXXII	...	1	Six	1	Death within 12 hours, but no intestinal lesions present.
XXXIII	...	1	Eight	...	At first there was considerable depression, but by the next day the animal appeared tolerably well; secretion of urine abundant.
XXXIV	...	1	Four	1	Counter-experiments were made with the fluid used in these three experiments: seven dogs being under observation at the same time; three having been treated with unboiled material and four with the boiled.
XXXV	...	1	Four	...	
XXXVI	...	1	Four	...	
Total...15	10	5	...	7	

It will be observed that the principal phenomena induced by the toxic material injected in these cases do not differ in their characters from those in which solutions of other decomposing organic substances were introduced into the system, hæmorrhagic gastro-enteritis being the leading feature recognized at *post-mortem* examinations: but we presume that some difficulty would be experienced in maintaining two opinions with regard to the *degree* of toxic properties exerted by resorting to solutions of fresh choleraic excreta, instead of to solutions of the same material derived from healthy individuals. This will become still more evident when the data furnished by the observation on heated choleraic material has been considered.

Having on a former occasion discussed the nature of the lesions induced by the introduction of these varying solutions of decomposing organic matter, we do not consider it necessary to refer more definitely to them again, especially as the tables contain an abstract of the salient *post-mortem* appearances. In the present instance the question which we are desirous of testing is the *degree* of the toxic influence exerted by the various solutions.

It will be noted that in the foregoing two sets of experiments on choleraic material the mortality is considerable; in the case where heat was not employed fifteen cases, yielding positive results in seven, or equal to 46·6 per cent.; and in the other set, out of thirteen animals, seven were affected, or nearly 54 per cent.—the average number affected, of both combined, being exactly 50 per cent.

TABLE XVI.

(b)—The Choleraic material introduced being Fresh, *but subjected to* Heat.

Experiment No.	Vein selected.		Temperature.		Drachms injected.	Affected.	Remarks.
	Femoral.	Saphena.	Degree.	Minutes' duration.			
XXXVII	1	...	212°	Three	Six	1	The dog died within 8 hours, and the *post-mortem* was conducted 1¼ hour later. Intestines coated with soft gelatinous pinkish material, and the mucous membrane affected. Reddish serous-fluid in the pericardium.
XXXVIII	1	...	212°	Four	Four	...	
XXXIX	1	...	212°	Three	Four	...	The same fluid used as in the last.
XL	1	...	212°	Three	Seven	...	
XLI	1	...	212°	Three	Four	...	The same fluid was injected unboiled without result in Exp. XXX, Table IV.
XLII	...	1	212°	Three	Six	1	Death within 6 hours after considerable purging. The small intestines contained watery fluid and numerous whitish flocculi. The mucous surface coated with a creamy layer, beneath which it was found to be extremely congested, and in some parts disintegrated. The large intestine also contained fluid.
XLIII	...	1	212°	Three	Four	1	This animal was treated in precisely the same manner as the last, with the same fluid and at the same time. Death took place here also within 6 hours. The symptoms had been the same, and the *post-mortem* appearances also, except that there was less watery fluid in the intestine.
XLIV	...	1	212°	Three	Eight	1	The animal was killed on the second day. There had been no very marked symptoms of illness, nor were there any marked lesions observed at the *post-mortem* examination, except that the last two feet of the small intestine had evidently been materially affected.
XLV	...	1	212°	Three	Eight	1	Died within 5 hours after having passed copious fluid stools and manifested symptoms of considerable pain. The material used was the same that was employed in the last experiment, as also in Exp. XXXIII, Table IV, but in the latter case unboiled and with a negative result. A *post-mortem* examination was made immediately after death. The intestines were full of watery and slimy fluid. The venous blood was very dark: no bacteria could be detected in it.
XLVI	...	1	212°	Three	Four	1	Died within 12 hours. No very marked *post-mortem* lesion, the principal being peritonitis.
XLVII	...	1	212°	Three	Four	1	Died within 15 hours.
XLVIII	...	1	212°	Three	Four	...	Unaffected.
XLIX	...	1	212°	Three	Four	...	Not much affected.
							The fluid injected in the last four experiments was derived from the same patient, a well-marked case of cholera; and counter-experiments were made with it, without boiling, in three other dogs, two of which yielded no results. (*Vide* Exp. XXXIV—XXXVI, Table XV.)
TOTAL...13	5	8	...	...	...	7	

TABLE XVII.

(*c*)—*The Choleraic material introduced having become* Putrid.

Number of Experiments.	Vein selected.		Drachms injected.	Material not heated.	Material heated.			Affected.	Remarks.
	Femoral.	Saphena.			Heated.	Temperature. Degree.	Minutes' duration.		
L	1	...	Four	1	...	...	...	...	The material injected was obtained from a *post-mortem* examination 3½ hours after death. Previous to the operation the temperature of the dog was 101°; 13 hours after the operation 103°; from the second day to the sixth its temperature was 102° without any special symptoms being manifested.
LI	1	...	Four	1	...	...	...	...	The material injected was obtained from a *post-mortem* examination, but not from the same patient as the last. The dog died within 12 hours, but manifestly of embolism.
LII	1	...	Six...	1	...	...	...	...	The material employed here also was from the intestine of a patient 5 hours after death. The animal was not materially affected during the three days it was under observation.
LIII	1	...	Four	...	1	212°	Three	...	The same material used as in the last, but in this case boiled before straining.
LIV	...	1	Eight	...	1	212°	Three	...	The same material was used in Exp. LIV, LV, LVI on the first, second and third day after it had been obtained from a cholera patient. Only one dog was appreciably affected.
LV	...	1	Six...	...	1	212°	Three	...	
LVI	...	1	Six...	...	1	212°	Three	1	
LVII	...	1	Eight	1	...	...	...	...	The fluid employed as in Exp. LIV, LV, LVI, but unboiled.
Total 8	4	4	...	4	4	...	...	1	

The positive results recorded in the foregoing Table (No. XVII) are not so numerous as were the results obtained in our previous experiments with putrid material, or in those now recorded on perfectly fresh choleraic material. This, possibly, is owing to the comparatively few experiments that have been undertaken on this occasion. Of the eight animals experimented upon, only one was materially affected, and it so happens hat in that case the material introduced had been subjected to a temperature of 212° F. a few minutes previous to being injected.

To sum up the results recorded in the tables of this section, showing the effect of the injection of choleraic alvine discharges into the veins of animals (Tables XV—XVII), it may be stated that of the thirty-six observations tabulated, fifteen yielded positive results, or somewhat less than 42 per cent. In nineteen experiments the material was not subjected to heat, and in seventeen cases the material had been heated up to 212°; the mortality from the former proved to be 36·8 per cent., and

that of the latter 47 per cent.,—thus proving that heat applied to this extent, at all events, had not diminished the toxic influence of the substance experimented with.

It is of very great importance to know definitely what is the effect of heat upon such organic substances as are known to be capable of manifesting virulent properties when introduced into the animal economy. This agent appears to us to offer a more trustworthy means than any other for ascertaining whether or not the active principle of these poisons is transmitted by infection with certain *vitalised* particles. In ultimate relation to this subject, as recently pointed out by Dr. Bastian in his remarkably suggestive essay on "Heat and Living Matter," are many important questions with reference to the process of disinfection, "where we have to do with articles of furniture or wearing apparel used by a person suffering from a contagious disease. Because in such a case, what we ought undoubtedly to know is whether the temperature of boiling water or even some lower temperature suffices to kill any living particles which may act as so-called 'germs of disease.' This is a subject upon which there should be no room for doubt."*

We had hoped to have been able to have submitted on this occasion a series of experiments regarding the effect of heat upon the infecting principle in two undoubtedly contagious diseases—small-pox and vaccinia. The observations which we have commenced are not yet in a sufficiently advanced state to be published. We have, however, been able to satisfy ourselves to a certain extent with regard to the action of heat on another well-known animal secretion possessing most virulent properties, namely, Snake-poison.

Last April we were asked by Dr. Ewart, the President of the Snake Commission, to undertake some microscopic examinations of fresh virus of the Cobra and of an Australian snake.† In order to conduct these examinations, Dr. Vincent Richards caused several snakes to eject their poison into a watch-glass in our presence. The poisons from the two species of snakes were transferred into separate test tubes, having been previously diluted with about five parts of distilled water. Each sample was subsequently divided into two parts: One test tube, containing the simple aqueous solution of the virus, was set aside; the other test tube, containing the remaining half, was placed in a vessel of hot water and thoroughly boiled for ten minutes.‡ This proceeding enabled us to carry out two series of observations—(I) with unboiled and boiled aqueous solutions of virus obtained from the Cobra; and (II) with unboiled and boiled solutions of the virus from the Australian snake:—

* *Contemporary Review*, September 1874, p. 517.

† These microscopic examinations need not be specially referred to here, as the results are embodied in the report which has just been issued by that Commission. Suffice it to say, that we could distinguish no cells or organisms of any kind in the poison which were not equally present in the inert secretion obtained from the fauces of the snake. On several occasions, however, we observed that acicular feathery crystals had formed on some of the slides, and that numerous fusiform crystals were precipitated in the course of two days from the aqueous solution of the virus. All these will be found figured in the report referred to.

‡ On being placed in the warm water, the solution of virus in the test tube soon became turbid, and a flocculent precipitate was seen to form long before it had been heated to boiling point.

SERIES I.—*Experiments illustrating the effect of Heat on the Virus of a Cobra.*

EXPERIMENT 1.—Injected 20 minims of the diluted virus (24 hours old) by means of a sub-cutaneous syringe into the thigh of a fowl. Died in 13 minutes 10 seconds.

EXPERIMENT 2.—Injected 20 minims of the diluted poison, previously *heated* to 212° F., into the thigh of a fowl—the poison 24 hours old. Died in 32 minutes 45 seconds. The symptoms in both cases were precisely the same.

EXPERIMENT 3.—Injected 20 minims of the diluted virus, not heated (48 hours old), into the thigh of a fowl. Died in 12 minutes 15 seconds.

EXPERIMENT 4.—Injected 20 minims of the diluted virus, heated to 212° (48 hours old), into the thigh of a fowl. Died in 44 minutes.

The solutions of the virus used in Exp. 3 and 4, having become 48 hours old, contained active bacteria; the boiled sample, however, contained far more than the unboiled.

All that remained of the virus used in the four foregoing experiments, now seventy-six hours old, was put into a single test tube and still further diluted with distilled water. The tube was then partially submerged in hot water in a closed vessel and thoroughly boiled for ten minutes. The boiled solution exhaled a very offensive odour, something like putrid fish. This was filtered, and the clear fluid obtained used in the following experiment:—

EXPERIMENT 5.—20 minims of the above boiled and filtered solution of snake-venom were injected into the thigh of a strong fowl. The animal became drowsy in the course of half-an-hour, and subsequently presented all the symptoms manifested by the former animals, only in a milder degree. Died in 4 hours 43 minutes.

SERIES II.—*Experiments illustrating the effect of Heat on the Virus of an Australian Snake.*

EXPERIMENT 1.—Injected 15 minims of the unheated and unfiltered solution of the virus (quite fresh) into the thigh of a fowl. Died in 2 hours 16 minutes.

EXPERIMENT 2.—Injected 20 minims of a filtered solution of fresh virus (which had been heated to 212° F. as in Series I) into the thigh of a fowl. Died in 2 hours 23 minutes.

EXPERIMENT 3.—Injected 20 minims of the unheated solution of the virus (24 hours old) into the thigh of a fowl.

EXPERIMENT 4.—The same as Exp. 3.—Both fowls died within 24 minutes.

EXPERIMENT 5.—Injected 20 minims of a solution of the virus (48 hours old), heated to 212° F., into the thigh of a fowl.

EXPERIMENT 6.—The same as Exp. 5.—Both fowls were found dead 49 minutes after the introduction of the poison.*

These experiments do not, as far as we are aware, differ materially in their results from those performed by Drs. Fayrer, Lauder Brunton, and others. From them it will be seen that heat applied in the manner and to the extent mentioned in the text does not materially modify the poisonous action of the virus of the snake. The heat resorted to was considerably more than sufficed to precipitate the fibro-albuminous material in it, and was, it may be presumed, sufficiently high and prolonged to destroy any protoplasmic bodies which it may have contained. The activity of the fluid did not seem to have suffered by being deprived of its fibro-albuminous constituents by precipitation and subsequent filtration; nor would the poison appear to be of a very volatile character.†

Taken altogether, these particular observations would seem to suggest that we should look to the chemist rather than to the histologist for further information regarding the nature of the active principle in the virus of the snake.

B.—Experiments on the effect of transferring Inflammatory Products from a serous cavity of one animal to that of another.

With a view of ascertaining for ourselves whether an ordinary inflammation in one of the serous cavities would, as is so frequently stated, produce a fluid increasing in virulence by transfer from one animal to another, we have made seventy-three special observations on very nearly as many pariah dogs. It seemed desirable that the statement which has been so frequently advanced on this point should be tested in this country, especially as the procedure seemed to offer a favourable field for the discovery of some clue to one or other of the many inexplicable phenomena of cholera and other epidemics. These experiments have materially helped us in coming to a very definite opinion as to the connection of bacteria with inflammatory or other diseased states. Of the seventy-three, thirty-five were required in order to supply an inflammatory virus to test the virulence of the secondary and subsequent products. As the animals thus subjected to experiment were utilised in other ways, and are referred to elsewhere, it is not necessary to tabulate the individual experiments.

In eleven cases a purely chemical irritant (such as tincture of iodine and tincture

* In order to satisfy ourselves from personal observation that fowls are not particularly prone to succumb after the introduction of putrid animal matters into their tissues, a fowl was treated in precisely the same manner as the foregoing, except that 20 minims of a solution of highly putrid animal matter was substituted for the snake-venom. Apparently not the slightest effect was produced, and the bird escaped next day.

† After these experiments had been completed, we learnt incidentally that the attendant who had been instructed to throw the poisoned fowls away had in no single instanc e complied with this order, but had taken them to his own home, and that he and his family had eaten them. No evil consequences ensued.

of iron) was employed; and in the remaining twenty-four a solution of various excrementitious substances—a little tincture of iodine being added to the latter in two instances. Out of the eleven experiments just referred to, inflammatory exudation was obtained from seven; and from the other group of twenty-four experiments, a similar fluid was obtained in fourteen. It will therefore be seen that the results were positive in twenty-one out of thirty-five cases, or at the rate of 60 per cent.

The following table will show the effect of transferring the morbid exudation thus obtained—whether injected when perfectly fresh, after a delay of twenty-four hours, or after being subjected to heat:—

TABLE XVIII.

Showing the result of injecting solutions of Inflammatory Products into the Peritoneal Cavity of Animals.

Number of Experiment.	FLUID INTRODUCED ABOUT HALF AN OUNCE.			Affected.	Remarks.
	Not heated.		Heated to 212°.		
	Fresh.	1 day old.	Fresh.		
1	1	...	...	...	The fluid used in this experiment had been obtained from the peritoneal cavity of a dog in which peritonitis had been induced by the injection into its peritoneum of about an ounce of the watery contents of the small intestine of a man who had died of cholera. The second dog was in no way affected by the operation.
2	1	...	...	...	... ...
3	...	1	...	...	... ...
4	1	...	...	...	... ...
5	1	...	...	...	The fluid introduced in this instance was diluted, purulent matter, which had been obtained from an abscess which had formed in the subcutaneous tissue of the same dog.
6	1	...	...	...	... ...
7	1	...	...	...	... ...
8	1	...	...	1	Intense inflammation of peritoneum, pleura, and pericardium: death had occurred within 12 hours. The fluid originally injected had been obtained from the peritoneal cavity of a dog, in which peritonitis had been produced by the introduction of a solution of normal alvine discharge 24 hours old.
9	1	...	...	3	Death within 6 hours. The fluid which brought this about had been obtained from the dog in Exp. 8. Consequently, it was the third removed from the original irritant. The *post-mortem* appearances were the same as in the last.
10	1	...	...	1	Death within 5 hours. The fluid in this case was the fourth removed, having been obtained from the dog used in Exp. 9. Unfortunately our supply of animals ceased for a couple of days, so that we were unable to carry this series any further.
11	...	1	...	1	Peritonitis, pleurisy, and pericarditis, with sanguineous fluid in the pericardial sac. The primary inflammation had been induced by means of a solution of normal alvine discharge introduced into the peritoneum of another dog two days previously.
12	...	1	...	...	The fluid used had been obtained from the dog in Exp. 11, and was consequently the second removed.
13	...	...	1	...	No effect beyond slight congestion of the peritoneum. The fluid injected had been strained subsequent to boiling.
14	...	...	1	...	The same fluid used as in the last, but it was not strained subsequent to boiling.

TABLE XVIII (*continued*).

Showing the result of injecting solutions of Inflammatory Products into the Peritoneal Cavity of Animals.

Number of Experiment.	FLUID INTRODUCED ABOUT HALF AN OUNCE.			Affected.	Remarks.
	Not Heated.		Heated to 212°.		
	Fresh.	1 day old.	Fresh.		
15	...	...	1	...	Fluid injected, obtained from the same source.
16	1	...	...	...	
17	1	...	...	...	Ditto ditto ditto.
18	1	...	...	...	Ditto ditto ditto.
19	1	...	...	...	Ditto ditto ditto.
20	1	...	...	1	The morbific agent obtained from the same source, a dog in which peritonitis had been produced by the introduction of a mixture of excrementitious matter from a former dog. Both animals died within 12 hours.
21	1	...	...	1	
22	1	...	...	...	The fluid resorted to was obtained from the peritoneal cavity of the dog in Exp. 21, and was therefore the second removed.
23	1	...	...	...	Precisely as in Exp. 22.
24	1	...	...	...	Fluid obtained from Exp. 20: it was therefore the second removed.
25	1	...	...	1	Precisely as in Exp. 24; but in this case death resulted in 8 hours, with well-marked exudation on the peritoneum and in the intestines.
26	...	...	1	...	Precisely as in Exp. 22, but the fluid had been boiled.
27	1	...	...	...	The same fluid employed in these four Experiments: in Exp. 29 and 30, however, the material injected was 24 hours old.
28	1	...	...	...	
29	...	1	...	...	
30	...	1	...	...	
31	...	...	1	...	In both cases the fluid injected was obtained from the same animal.
32	1	...	...	...	
33	...	...	1	...	Ditto ditto ditto.
34	1	...	...	...	
35	1	...	...	...	The fluids employed in the foregoing four Experiments (31—34) mixed. No result.
36	1	...	...	...	The morbific agent obtained from the same animal in both cases. Both unboiled and boiled yielded negative results.
37	1	...	...	...	
38	...	1	...	...	
38	26	6	6	7	

The above Table shows that out of thirty-eight animals in which the product of peritonitis* was introduced into the abdominal cavity, only seven, or 18·4 per cent., either succumbed or were unmistakably affected—a considerably lower percentage than that obtained when solutions of ordinary excrementitious matters were used; for, of the animals experimented upon with the latter substances, about 70 per cent. succumbed.

The remarkable fact, however, appears that of the seven deaths referred to in the last paragraph, three were due to a virus obtained by inoculating from animal to animal in one series of experiments (in Nos. 8, 9, 10, Table XVIII), and, so far as we

* It would be more correct to state that in thirty-seven instances the product of peritonitis was resorted to, as in one instance the fluid obtained was from an abscess which had formed in the abdominal walls, and which did not seem to communicate with the cavity of the peritoneum.

know, the number might have been unlimited had we at that time had a sufficient supply of animals to have carried on the observation without interruption.

In three others, out of the seven, we were unable to transfer the influence of the septic matter (contained in the decomposing substance resorted to in the first instance) to excite inflammation beyond the second animal; and in only one (out of several attempts) were we able to observe its toxic influence on a third. Whereas, in the three cases cited, four animals in succession rapidly succumbed to the effect of the virus contained in, or initiated by, a solution of ordinary alvine discharge.

This result cannot be attributed to mere idiosyncrasy on the part of the animals in question; for not only in the experiments on peritonitic fluid has this phenomenon been observed, but in all cases where several experiments were carried out on the introduction of decomposing organic matter into the system. No matter by what channel they were introduced, certain solutions have manifested singularly virulent properties—properties which, hitherto, we have not been able to identify with any physical or chemical peculiarity.

C.—Summary: With remarks on the probable Nature and relative Degree of Virulence of the toxic elements in Choleraic and other Alvine Discharges.

The experiments just recorded agree in their general results in a marked manner with those which we have previously published, and quite bear out the inferences which we then felt justified in placing on record; but as the element of number is of such consequence in obscure questions of this nature, we have thought it advisable to bring together all the observations which have been detailed in this and in our former report, so that the lesson which it is possible for such a series of experiments to convey may be the more readily perceived.

TABLE XIX.

Total Experiments on the Effect of the Introduction of Solutions of Organic Substances, from various sources, into the Circulation of Dogs.

Number of Experiments conducted.	Infecting material selected.	Where introduced.	Number affected.	Percentage of affected.
76	Solutions of choleraic evacuation	Vein ...	34	44·7
26	Solutions of normal evacuation	Vein ...	7	26·9
26	Solutions of various excrementitious matters ...	Peritoneum ..	20	76·9
42	Peritonitic exudation	Peritoneum ..	10	18·4

From this table it will be seen that strained alvine discharges from persons suffering from cholera have been introduced into the veins of dogs on seventy-six occasions, with positive results in thirty-four, or at the rate of 44·7 per cent.

The result of a similar series of experiments with, by no means weak, solutions

of normal alvine discharges (certainly not of lower specific gravity than the choleraic fluids) was not much over half that obtained from the former material; out of twenty-six experiments, in seven only were the animals affected, or at the rate of 26·9 per cent.

It appears from these results that the dejections of persons suffering from cholera, and also those of persons in good health, when injected into the veins, act in some cases as a poison—have the power of producing a definite effect on the intestinal mucous membrane, resulting in a disorganization of its substance.

The symptoms and pathological changes induced by both varieties of material, the choleraic and non-choleraic present no differences: but, so far as our experience goes, the proportion of cases in which this result is attained when choleraic fluids are employed, is considerably larger than when non-choleraic material is used.

A closely allied phenomenon has been observed in connection with those experiments in which the material has been made to reach the circulation indirectly by means of the lymphatics in a serous membrane. We have, however, already touched on this subject in the paragraph referring to our experiments on the question of the increase in intensity of the virulent properties of inflammatory products as necessarily dependent on transference from one animal to another (page 177).

We have found that such an increase is by no means the ordinary result of the transfer—our experience being based on sixty-eight experiments; for, whereas the introduction of solutions of excrementitious matters into the peritoneum on twenty-six occasions was followed by serious inflammation and commonly death in twenty instances, or nearly 77 per cent. of the cases, similar experiments in forty-two cases with the fluid product resulting from such primary inflammation was only successful in ten, or 23 per cent.

With two specimens of exudation only were we able to transfer the morbid action more than twice—once in the present series of experiments and once in the former—but on those two occasions the virulent properties manifested were unmistakable. In one case the original irritant employed was a decomposing solution of meat, ninety-six hours old, and in the other a solution of ordinary alvine discharge.

Conclusions:—Why the material, whether choleraic or non-choleraic, should exert its power in some instances and not in others, or why choleraic material would appear to possess this power more frequently than ordinary material, we cannot explain; but we are inclined to believe that the possession of these toxic properties will be found to depend on some variation—it may be only a trifling variation in composition which decomposing organic substances undergo. Something, however, is present which, as we have already said, is capable of exercising a singularly pernicious effect on animal life, the most prominent local manifestation of its action being observed in the intestinal canal.

What is this something? Is it visible? Is it a living substance?

With regard to the first of these questions, we would not presume to speak decisively, although we ourselves have searched for it in vain with lenses which have the reputation of being the very best hitherto constructed, and have been uniformly unsuccessful in associating it with any constant visible phenomena.

With regard to the second question, the reply will be satisfactory, or otherwise, according to the particular view entertained as to what the tests of vitality are. On this vexed question we do not venture to offer an opinion—whether, for example, any substance or condition which would cause the coagulation of albumen (animal and vegetable) would or would not be sufficient to destroy the vitality of the entity, be it "egg," "seed," "germ," or "plasma," we cannot say. This, however, we affirm that in our own experience we have seen no living object preserve its vitality after exposure in a fluid to a temperature approaching to 212° F., nor have we been able to satisfy ourselves that any one else has done so.

A reference to the Tables of Experiments will show that the application of heat up to boiling point did not, apparently, modify the toxic properties of the particular substances tested; for out of seventeen instances in which choleraic alvine discharges were thus treated before introduction into the veins of dogs, eight became affected, or 47 per cent.—a slightly larger percentage than the unboiled fluids had yielded; and out of thirteen cases in which ordinary alvine discharges had been similarly experimented with, three were affected, or 23 per cent.—some two or three per cent. lower than had been the average when the unboiled material had been resorted to.

Therefore, until it be proved that living substances can withstand immersion in a fluid at a temperature of 212° F. of some minutes' duration, we have no hesitation in stating that the morbid phenomena which we have observed to follow the introduction into the animal economy of strained solutions of choleraic and normal alvine discharges, and of other decomposing animal substances, are not the result of infection with a material the poisonous properties of which are dependent on its possessing vitality.

III.—EXPERIMENTS ON THE SECTION OF THE SPLANCHNIC AND MESENTERIC NERVES.

After the issue of our last report, an additional series of experiments regarding the effects of nerve-sections was carried on, with the view of finally satisfying ourselves whether any destruction of epithelium or denudation of the mucous membrane were necessary for the occurrence of a copious effusion of fluid into the intestinal tube, and also whether the observations which we had previously made regarding the coincidence of such effusion with partial but not with total deprivation of nervous supply, would stand the test of repeated experiments.

The following table shows the result of twenty-one experiments on section of the mesenteric nerves:—

TABLE XX.

Section of Mesenteric Nerves.

No.	Nature of operation.	Result.
1	Complete section of nerves of a loop of intestine.	Exudation of watery fluid. Loop half full of fluid, and containing some loose mucous flocculi.
2	Section of mesenteric nerves	Loop distended with grey watery fluid containing gelatinous flocculi. Surface of mucous membrane soft, thickened and covered with a gelatinous layer of material similar to the flocculi. Fluid strongly alkaline; smell mawkish and choleraic; contained about $\frac{1}{6}$th of albumen. Flocculi composed of exudation cells. Gelatinous layer on mucous membrane composed of similar cells in a mucoid basis.
3	Section of mesenteric nerves	Exudation of fluid; reddish; sp. gr. 1,009; alkaline; containing albumen.
4	Section of mesenteric nerves	Loop distended with fluid; pinkish grey; strongly alkaline; odour choleraic; sp. gr. 1,006. Surface of mucous membrane soft, thickened and covered with a loose yellowish layer of exudation cells.
5	Section of mesenteric nerves	Mucous membrane soft, moist and thickened, but no exudation. The ligatured loop was situated in the jejunum.
6	Section of mesenteric nerves	Loop fully distended with fluid; reddish; sp. gr. 1,005; alkaline; containing a few flocculi.
7	Section of mesenteric nerves	Loop fully distended with fluid.
8	Section of mesenteric nerves	Loop contained an abundance of fluid. It was situated in the jejunum.
9	Complete section of mesenteric nerves	No fluid in the loop.
10	Section of mesenteric nerves	Fluid exudation.
11	Section of mesenteric nerves	" "
12	Section of mesenteric nerves	No special exudation in the centre loop.
13	Complete section of mesenteric nerves	Loop full of brownish gelatinous exudation containing numerous large bioplasts.
14	Complete section of mesenteric nerves	Abundant exudation of fluid.
15	Complete section of mesenteric nerves	Loop almost empty.
16	Complete section of mesenteric nerves	Loop fully distended with fluid; straw coloured; alkaline; sp. gr. 1,008.
17	Complete section of mesenteric nerves	Loop fully distended with fluid; alkaline; containing an abundance of granular exudation cells.
18	Complete section of mesenteric nerves	Loop distended with fluid, swarming with bacteria and vibriones. *Post-mortem* some hours after death.
19	Complete section of mesenteric nerves	Loop distended with fluid. Mucous membrane thickened and moist.
20	Complete section of mesenteric nerves	Loop fully distended with fluid, watery, almost colourless; sp. gr. 1,005; reaction alkaline. A few projecting flocculi containing exudation cells on the surface of the mucous membrane.
21	Complete section of mesenteric nerves	No special exudation in the ligatured loop.

It will be seen that a copious secretion of fluid was the almost invariable result of section of the nerves, entirely independent of detachment of the epithelial covering of the mucous membrane, but sometimes associated with the occurrence of an exudation of bioplasts upon its surface; and that the secretion occurred as well in cases in which the division of the nerves was complete as when it was only partial. These results are similar to those obtained by us in the greater number of the experiments of this nature which we referred to on a former occasion, and are quite in accordance with those obtained originally by Moreau. Moreau's experiments have

also been confirmed by Dr. Lauder Brunton. Those of the cases in our report for 1872 in which complete division was found to be unaccompanied by an abundant secretion, must, therefore, be looked upon as accidental; and, from extended experience, we would incline to ascribe the occurrence to incompleteness in the isolation of the ligatured loop, or to escape of the fluid owing to rupture of the gut as a result of ulceration at the site of ligature and of the pressure exerted by the contained fluid: both these accidents were more than once observed to have occurred and to have modified the results of the experiments accordingly.

Only a few experiments on section of the greater splanchnic nerves were tried, as the results were entirely similar to those in the previous series of such sections. The following table shows the nature of the operation and the result in seven cases:—

TABLE XXI.

Section of the Splanchnic Nerves.

No.	Nature of operation.	Result.
1	Section of left greater splanchnic nerve; and excision of semilunar ganglion.	No result.
2	Section of left greater splanchnic; excision of semilunar ganglion; and ligature of rectum.	No result.
3	Section of both greater splanchnics	Died 36 hours afterwards with dysenteric symptoms.
4	Section of both greater splanchnic nerves and ligature of rectum.	No result.
5	Section of left greater splanchnic and ligature of colon.	No result. Urine; sp. gr. 1,040; no sugar; no albumen.
6	Section of both greater splanchnics	No result.
7	Section of left greater splanchnic; and excision of semilunar ganglion.	No result. Urine contained neither sugar nor albumen.

It appears from this that no result similar to that dependent on section of the mesenteric nerves can be induced by division of the splanchnic nerves, even when this is combined with excision of the semilunar ganglia.

CALCUTTA,
October 1874.

THE SOIL IN ITS RELATION TO DISEASE.

A REPORT OF OBSERVATIONS

BY

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1875.

THE following Report embodies the results of observations which have been carried out with a view of determining to what extent peculiar conditions or changes of condition in the soil in Calcutta affect the prevalence of disease in general, and of certain diseases in particular.

The phenomena forming the subjects of observation were:—

(1) The amount of moisture in the soil;
(2) The temperature of the soil; and
(3) The amount of carbonic acid in soil-air.

As is well known, marked attention has lately been directed to the importance of soil-meteorology as affecting the prevalence of disease, and it formed one of the subjects to which our attention was directed by the Army Sanitary Commission and by Dr. Parkes. Most careful observations have been published by Dr. Max von Pettenkofer and other savants regarding it—indeed, it was at the special suggestion of Dr. von Pettenkofer that some of the observations here recorded were undertaken.

Observations on the varying conditions of soil-moisture as indicated by water-level and rain-fall have been carried out in many places in India for some years, and although, owing to the difficulties incident on the beginning of any entirely new series of observations, the results have not as yet been so generally satisfactory as might have been desired, still a large number of thoroughly trustworthy data have been already accumulated regarding the matter. These will be made the subject of a special Report hereafter; in the meantime, we have limited ourselves to the consideration of the phenomena observed during a complete year in Calcutta, where the observations have been conducted so as to furnish data for comparison with similar observations which have been, and may still be, recorded elsewhere in India.

Observations on the temperature and carbonic acid-contents of the soil have never, so far as we are aware, been carried out in this country, and even in Europe they

have been made only in a few isolated localities. We would therefore take the present opportunity of pointing out their value and of pressing on the attention of the Meteorological Department the importance of investigating and recording some of the more prominent features of sub-soil phenomena.

From an etiological point of view it is obviously quite insufficient to be informed merely of atmospheric meteorology and to remain in total ignorance of telluric conditions. This view of the case is becoming more and more realized in Europe, and the value and importance of acquiring the necessary data in this country cannot be over-estimated.

We have thought it better to confine our attention to the consideration of the phenomena presented by a period during which our observations on soil-conditions were most numerous and of the most varied nature, but data regarding water-level and soil-temperature for a considerably longer period are given in the accompanying tables.

The period specially considered ranges from the month of July 1873 to August 1874, and for this period full details are given regarding the temperature and carbonic acid-contents of the soil at 3 and 6 feet from the surface. The coincident phenomena of rain-fall, atmospheric temperature, and velocity of wind are also given, together with the statistics of total mortality; of mortality from cholera; and of the prevalence of fever and dysentery.

Figures regarding all these phenomena will be found in the tables (I—VI), and the relations which they bear to one another are, moreover, graphically represented in a series of diagrams of graduated curves. An additional chart has also been constructed showing the monthly fluctuation in the carbonic acid of the soil-air as compared with the results of the experiments conducted in Munich by von Pettenkofer.

(1.)—Mode in which the Observations have been conducted and the sources of the various Data. Description of apparatus employed to obtain the air from the soil.

It will be convenient, before proceeding to describe the results of the observations, to give a brief account of the sources from which the data were derived and the means by which they were obtained.

(a)—Carbonic Acid of the Soil-Air.

The data on this point were obtained by our own observations. During a considerable portion of the period under review the experiments were made with regard to one locality only, but subsequently another series was undertaken so as to ascertain the amount of carbonic acid in two localities separated from each other by about 50 yards.

The depths selected for observations were in both cases 3 and 6 feet respectively;

observations at a lower level were not attempted, as it did not seem to be desirable to go deeper into a soil such as that of Calcutta where the water-level is for a considerable portion of the year so superficial as to cause saturation of the soil at a short distance beneath the surface.

The method adopted for conveying the air from the soil at these depths was very simple. Two lead tubes were procured, and at one end of each a hollow perforated bulb was soldered. A pit was dug in the soil—the ordinary alluvial soil of Calcutta—perfectly free from all sources of surface pollution, and which had probably not been disturbed for a quarter of a century. One of these tubes was passed through the bottom of an ordinary flower pot, inverted, and perforated in numerous places. Below and surrounding this pot fragments of earthenware were arranged so as to keep the earth from plugging the orifices in the bulbous extremity of the leaden tube. The pit was now filled up to within 3 feet of the surface and the other tube introduced and similarly protected from being plugged by the fine soil; the earth was then heaped up and well beaten down, until it reached the level of the surface.

The other pit was of a similar kind, and the leaden pipes were introduced and protected in the same manner. The observations in each case were not undertaken until a considerable period had elapsed, so as to allow the soil to regain its ordinary condition.

The tubes were then conducted into a room and attached to an aspirator capable of holding thirty-eight and a half litres.

The remarks made by Dr. von Pettenkofer with reference to the ease with which air could be made to pass either way through the tubes which he had introduced into the earth apply with equal force to our own tubes. Air could be blown through the tubes with the greatest ease, so much so that we could not for certain distinguish the pipes which had been lodged in the earth from a pipe of similar length placed alongside them, but with both its ends opening into the free air by blowing alternately through them. This fact of itself testifies to the readiness with which intercommunication occurs between the atmosphere and the sub-soil air.

Attached to the aspirator—intervening between it and the pipe leading into the soil—were the usual appliances for estimating the amount of carbonic acid by the Baryta process, as devised by von Pettenkofer many years ago, and which is fully explained in all modern treatises on chemistry. Briefly described, the method consists in causing the air under examination to pass through a flask containing a solution of baryta of known alkalinity, and subsequently ascertaining how much of the alkalinity has disappeared (by the passage though it of air containing carbonic acid) by means of a standard solution of oxalic acid—turmeric paper being employed in preference to litmus for ascertaining the precise stage when the solution becomes neutral.

This information having been obtained, the precise amount of carbonic acid was calculated by the method usually adopted in connection with volumetric

analyses. As it is unnecessary to reproduce all these figures, we have confined ourselves to giving tables of the amount of carbonic acid per 1,000 volumes of soil-air at 0° C. and at 760 m.m. barometric pressure. Our acknowledgments are due to Mr. C. H. Wood, the Officiating Professor of Chemistry at the Medical College, for valuable aid in indicating the simplest and most accurate method of recording the data required in connection with this matter.

(*b*)—*Soil-temperature.*

The data recorded on this point are also the result of our own observations and were obtained in the following manner:—A shallow shaft or well was sunk to a depth of slightly over 6 feet in the ordinary alluvium of Calcutta. The shaft having been made of sufficient capacity to allow of easy entrance, was lined with bricks and mortar. An opening was left in the floor to allow of easy drainage of any surface water which might obtain entrance, and two openings were left in the brickwork of one side of the shaft at depths of 3 and 6 feet, respectively, leading into wide tubes of perforated zinc, which penetrated the soil horizontally from the outer surface of the brickwork and terminated in open extremities in the earth.

These tubes were of sufficient diameter to allow of a narrow board, carrying the thermometers, being pushed into them. The thermometer board had a wooden plug and handle which fitted into the mouth of the tube whilst the opening in the brickwork was closed by an accurately adjusted wooden cover, and further secured by being coated externally with moist clay.

A thick wooden lid, covered by a layer of turf, closed the mouth of the shaft, and the entrance of rain or access of sun to the cover was prevented by means of a thatch roof about 5 feet above the ground.

Observations were made daily at 11 A.M., and the thermometers immediately returned to their places in the perforated zinc tubes let into the earth, care being taken to raise the temperature of the minimum and to depress that of the maximum, respectively, considerably above and below the temperature of the soil.

(*c*)—*Open-air temperature*; (*d*)—*Rain-fall*; *and* (*e*)—*Wind-velocity.*

The figures in Tables I—VI, upon which the charts are based, of daily and average weekly atmospheric temperature; of rain-fall; and of the velocity of the wind were obtained from the "Abstract of the Results of the Hourly Meteorological Observations taken at the Surveyor General's Office, Calcutta" as published in the Proceedings of the Asiatic Society of Bengal; but the monthly statements in Table VII of the atmospheric temperature and rain-fall are from the Annual Reports of the Meteorological Reporter to the Government of Bengal.

(f)—Water-level.

The observations on the fluctuation in the water-level are those which have been registered under the superintendence of Dr. Sidney Lynch at the Alipore Jail. The data extend from February 1872 to the present time. The *weekly* averages in the variations of level for one year's observations, the year specially under review, have been given; but only the monthly fluctuation for the remaining periods (Table VII, page 203) as the daily figures, or even those of the weekly mean of the observations, would occupy too great space.

(g)—Statistics of Disease.

The figures of general mortality and of mortality from cholera which are given in Tables I to VI are those furnished to the Office of the Health Officer of Calcutta. Those regarding fever and dysentery are derived from the Hospital Registers of the Presidency and Alipore Jails; they represent, not the mortality, but the number of cases, and were selected as being presumably more accurate than those furnished by the Police to the Municipality. As the population of the jails averages only about 3,000, it was not considered large enough to furnish information with regard to the general prevalence of cholera with sufficient distinctness. We are under great obligations to both Dr. Sidney Lynch of the Alipore, and Dr. Coull Mackenzie of the Presidency Jails, for the valuable aid which they have given us on very many occasions in connection with our work and for the many data which they have always most readily placed at our disposal.

Having made these introductory explanations with regard to the data which we have brought together, we now proceed to consider the result of the observations as shown in the accompanying tables and diagrammatic charts.

(2).—The fluctuations in the amount of Carbonic Acid in the Soil.

It may be premised that the estimation of the amount of carbonic acid in the soil was not undertaken under the idea that this gas itself exerts much influence on the prevalence of disease, but because its amount may be taken as a convenient and fairly accurate index of the degree of the various organic processes taking place between the water-level and the surface.

(a)—Average amount of Carbonic Acid in the Soil of Calcutta as compared with that of Munich.—(Chart I.)

The levels at which the observations were made were not the same in the two localities, those in Calcutta being made at 3 and 6 feet from the surface; those in Munich at 5 and 14 feet. This must be taken into account in the comparison; still

allowing all due weight to this circumstance, very considerable differences are evident in the results.

In Calcutta, the *maximum* in the upper layer occurred in September, with 11 volumes per 1,000. In Munich, the *maxima* in the two years shown in the diagram occurred in August and July, respectively, with 10 and 14 volumes per 1,000. The *minimum* in the upper layer in Calcutta occurred in May with 4 volumes per 1,000. In Munich, in January and in March, with 2 and 3 volumes per 1,000, respectively.

The *maximum* in the lower layer occurred in Calcutta in September, with 12 volumes per 1,000. In Munich, the *maxima* occurred in August and July, with 16 and 26 volumes per 1,000. In Calcutta, the *minimum* occurred in July with 7 volumes per 1,000; but in Munich in January and February with 3 and 5 volumes per 1,000, respectively.

(*b*)—*The fluctuations in the amount of Carbonic Acid in the Soils of Calcutta and Munich compared.*

In Calcutta, beginning with November, in the upper layer we find a gradual and continuous fall until May; a slight rise in June; a slight fall in July followed by a great and rapid rise in August and September. In Munich, beginning with the same month, we find slight falls to the *minima* in January and February; a slight rise and fall in March and April, respectively, followed by a rapid rise to the *maxima*.

In Calcutta, in the lower layer, again starting from November, we find a slight rise in December followed by a fall until March and April, succeeded by a slight rise in May and a fall thence to a *minimum* in July; the *minimum* being followed by a rapid rise to the *maximum* in September. In Munich, there is first a fall to the *minima* in January and February, and thence a continuous rise to the *maxima*.

Both localities agree pretty closely in the period at which the *maxima* occur, but the course of the fluctuations is otherwise very different, for while the *minima* in Calcutta occur in May and July, those in Munich occur in January, February and March.

There is also an agreement in the approximation of the periods of *maxima* and *minima* in the upper and lower layers of the two localities. There is considerable difference in regard to the relative amounts which the volumes of carbonic acid in the upper and lower levels bear to one another, but this cannot be regarded as of any importance, as it may have been due to the fact that the levels of observation were not identical.

There is, however, one point in regard to this relation in which a distinct difference can be traced in the two localities, for, whilst in Munich the quantities of carbonic acid in the two layers approach one another most closely when low, and are most remote when at a *maximum*, the reverse is the case in Calcutta—

the difference in amount being least during the period of *maxima*, and great when the amount of carbonic acid is low.

In Munich, the points of *maxima* and *minima* appear to be determined by temperature, whereas in Calcutta, as we shall see further on, this is not the case—moisture being the apparent determinant.

(c)—*The quantities of Carbonic Acid present at different times in the Upper and Lower Layers of Soil in Calcutta.*—(*Charts II and IV.*)

The chart illustrating the proportion of carbonic acid present in the layers of soil of the first locality selected for observation (Tubes No. 1) shows the weekly averages of the gas in 1,000 volumes of soil-air. There is not much calling for comment on this point; as the principal phenomena of the fluctuations in amount of carbonic acid have been already pointed out.

One curious phenomenon appears in regard to both layers of soil, namely, a sudden short rise in the amount of carbonic acid during the month of January. The amount of carbonic acid present in the upper layer in July 1874 was almost identical with that at the corresponding period of the previous year; while that in the lower layer was greater in the second than in the first year. In the upper layer a rapid rise is visible in June 1874, whilst in the lower the amount continued low until the close of the observations. So far as the evidence goes, it would appear that the period of *minimum* begins later, and is continued to a later date in the lower than in the upper layer.

The sudden depression in the upper layer in May is very remarkable, and no corresponding phenomenon occurred in the case of the lower layer. Various of these special phenomena characterising the separate layers may, apparently, be explained, as will appear further on, but in the meantime attention is merely directed to them.

The relations between the quantities of carbonic acid estimated in the upper and lower layers of soil in the second locality selected for observation—the set of tubes No. 2, Diagram IV—resembled those in the former locality, in so far that the amount of gas present in the lower layer of soil continuously exceeded that in the upper one. The absolute differences in the quantities present in the layers were, however, less.

The absolute *minimum* in the upper layer occurred in January with 3·8 volumes per 1,000, but second periods of extreme depression occurred in February and July. The *maximum* for the period of observation occurred in January—6 volumes per 1,000.

There were two periods of *maximum* amounts of carbonic acid in the lower layer, the first in January—7 volumes per 1,000; the second in May, also with 7 volumes per 1,000.

The absolute *minimum* occurred in August with 5 volumes per 1,000, but there was a previous period of depression in January and March, also with 5 volumes per 1,000. In both layers there was a rise in January.

Both localities agreed in constantly showing a larger quantity of carbonic acid in the lower than in the upper layer. For purposes of more exact comparison, attention must be confined to the period during which both localities were subjected to observation. When this is done it appears that the absolute quantities of carbonic acid present in the second locality were, as a rule, less than those in the first, but that the periods of relative depression and elevation in amount of carbonic acid exhibited a general coincidence in both places. In the second locality not only were the amounts of carbonic acid less, but the fluctuations in the quantities present at different times were also less than in the first locality. This comes out very clearly in the following statement :—

Layer.	First Locality.		Second Locality.	
	Maximum. Vols. per 1,000.	Minimum. Vols. per 1,000.	Maximum. Vols. per 1,000.	Minimum. Vols. per 1,000.
Upper	7	3	6	3
Lower	12	7	7	5

The only point of interest which calls for special remark in regard to this comparison is the demonstration which it affords of the occurrence of local variations in the amount of carbonic acid present in the soil of localities in close proximity to one another, and to all appearance extremely similar in their nature. The sites of observation were not more than 50 yards apart, and were both situated at similar and corresponding distances from the walls of one and the same building. The processes going on in the soil in the two places must have differed materially, in degree at all events, if not in kind ; and if such processes occurring in the soil have any influence on health, it is obvious that people inhabiting one end of the building must have been exposed to different hygienic conditions from those living at the other end. Such an observation is of special interest in connection with the extremely marked, and frequently apparently inexplicable, localisation in the distribution of cholera within narrow limits—even within the limits of individual buildings.

(*d*)—*Comparison of the amount of Carbonic Acid present in the Soil with the Temperature of the Soil at similar depths.*—(*Chart III.*)

On consulting the tables and charts it becomes at once clearly evident that the amount of carbonic acid present in the soil at various times is not determined by the mere coincident temperature of the soil. Maximum temperature coincides with minimum amount of carbonic acid at one period, and with a very large amount

of carbonic acid at another. The lines of temperature neither directly nor conversely correspond with those of carbonic acid. There is, however, one curious phenomenon which comes out very distinctly during the period over which the observations extend, and this is that the periods of *maximum* difference in the quantities of carbonic acid in the two layers of soil coincide with the periods of *maximum* difference of temperature in these layers. The *minimum* difference in the quantities of carbonic acid occurred in August and September, and during the same period the *minimum* difference of temperature also occurred. The two periods of *maximum* difference between the amounts of carbonic acid in the two layers of soil were first in December, January and February, and second in May; at both of these periods *maximum* differences in temperature were also present. Whether this be a mere coincidence we do not feel prepared to say, but it may be pointed out that if the conditions of temperature be in any way causatively related to the differences between the quantities of carbonic acid present in the layers of soil, the essential element is the *difference* of temperature, not the absolute temperature of either layer individually. The coincidence of *maximum* differences of temperature and carbonic acid occurred at one time when the temperature of the lower layer of soil exceeded that of the upper one, and at another when the reverse relation prevailed.

(e)—Comparison of the amount of Carbonic Acid present in the Soil with the Atmospheric Temperature.—(Chart III.)

No clear relation of any kind can be observed to exist between the atmospheric temperature and the amount of carbonic acid present in the soil—periods of extreme elevation and depression of the latter occurring coincidently with conditions of temperature showing no corresponding changes.

(f)—Comparison of the amount of Carbonic Acid in the Soil with the Rain-fall.—(Chart III.)

In this case a general coincidence of conditions appears very distinctly, the principal periods of rain-fall coinciding with the principal periods of elevation in amount of carbonic acid, and the main periods of depression in the latter coinciding with periods of drought. This general coincidence is, however, much closer and more marked in reference to the carbonic acid in the upper than to that in the lower layer of soil, for the amount of carbonic acid in the latter continues high long after the cessation of the rains, and shows no immediate rise corresponding with their commencement in the following season.

(g)—Comparison of the amount of Carbonic Acid in the Soil with Water-Level.—(Charts II—III.)

Here also a general coincidence appears, but in this case the coincidence is closer in regard to the lower than to the upper layer, as was seen to be the case with the rain-fall. The elevation of water-level begins later and lasts longer than the period of extreme elevation in the carbonic acid of the upper layer of soil.

(*h*) *Comparison of the amount of Carbonic Acid with the Velocity of the Wind.*—(*Chart IV.*)

The velocity of the wind does not appear to exert any very distinct influence on the amount of carbonic acid in the soil. It is, however, possible that the extreme and continued elevation in velocity of the wind during April and May may have been influential in producing the sudden depression in the amount of carbonic acid in the upper layer of the soil of the first locality in the latter month. There was no corresponding depression in the upper layer of the other locality, but as the latter was much more sheltered than the first locality, the discrepancy rather goes to support the idea that the wind may have had some effect. The question also arises, whether the marked elevation in amount of carbonic acid in both localities in January may not have been partially dependent on the long continuance of still weather, and consequent diminished ventilation of the soil, which preceded it.

(3.)—Temperature of the Soil.—(Chart III.)

Little need be said regarding this, as the principal phenomena appear very clearly in the chart. So long as the weather remains dry, the fluctuations in temperature in the upper layer of soil follow those of atmospheric temperature very regularly; but on the occurrence of rain this correspondence ceases. The fluctuations in the temperature in the lower layer are naturally much less marked and sudden, and the line of elevation and depression follows a long, gentle curve. The *maxima* of temperature in the two layers approach more closely than the *minima*, a point in which the relations of temperature correspond with those of carbonic acid. During the cold weather the temperature of the lower layer considerably exceeds that of the upper one. These relations are reversed during the hot weather. A period ensues on the onset of the rains, in which the temperatures of both layers are nearly alike —sometimes one, sometimes the other showing a slight excess—and this is followed by a prolonged and continuous fall of the temperature of the upper layer beneath that of the lower until the maximum difference is attained in January and February, coincident with the minimum absolute temperature.

(4.)—Water-Level.—(Chart II.)

The only point calling for special notice here is the demonstration afforded by the chart, that the water-level in Calcutta is really essentially dependent on the local rain-fall. In so far as weekly averages are concerned, the influence exerted by the tides is so slight as to be almost inappreciable, and the same holds in regard to drainage into the delta from the melting of the snows on the Himalaya, and other non-local supplies of water, which might have been expected to produce very evident effects in a soil such as that in and around Calcutta. The three years' Table (No. VII) demonstrates the same fact for a longer period.

(5.)—Relations which the different conditions of Soil bear to one another.—(Charts II, III, IV.)

The most important point to be noted in regard to this subject is the apparent dependence of the amount of carbonic acid in the soil on the degree of soil-moisture. When the latter is high, the carbonic acid is at its maximum, and the minimum periods of both also coincide generally. The facts already pointed out in regard to the behaviour of the carbonic acid-contents of the individual layers in reference to the rain-fall and water-level, very clearly indicate such a dependence; for, whilst the carbonic acid of the upper layer coincides more closely with the rain-fall than with the water-level, the reverse relation appears in the case of the lower layer of soil.

(6.)—Comparison of the prevalence of Disease with the occurrence of various conditions of Soil in regard to Carbonic Acid, Temperature and Water-level.—(Charts II—III.)

As regards the prevalence of cholera on comparing the figures and charts on this point, the only remarkable coincidence appears to lie in the converse relation which water-level, and in a less marked degree rain-fall, bear to the prevalence of this disease. When the latter is at a maximum, the water-level is at a minimum, and when the water-level is at a maximum, the prevalence of cholera is at a minimum. There is no such close coincidence either in regard to conditions of soil-temperature or amount of carbonic acid, although, in so far as soil-moisture appears to determine the amount of carbonic acid in the soil, there is a general coincidence in regard to the latter also. The relations between rain-fall and prevalence of cholera are not so strongly marked as those between the latter and the water-level; and it even appears as though the converse relation between conditions of water-level and prevalence of cholera were in some degree more distinct than the direct one between the water-level and the rain-fall.

The greatest prevalence of fevers during the period of observation occurred coincidently with the period of maximum carbonic acid and highest water-level.

There were two maximum periods of dysentery, one occurring during the rise in the water-level, and the other at a corresponding point in the course of its fall. No coincidence can be traced in regard to the other conditions of soil, save the carbonic acid of the upper layer which in this part of its course very closely corresponds with the water-level.

No very clear connection can be traced between the statistics of total mortality and the prevalence of any special conditions of soil. There were two periods of maximum mortality during the period of observation—one in November and December, coincident with marked prevalence of fever and dysentery; the other in April and May with maximum cholera.

The comparison of the prevalence of disease with the existence of special

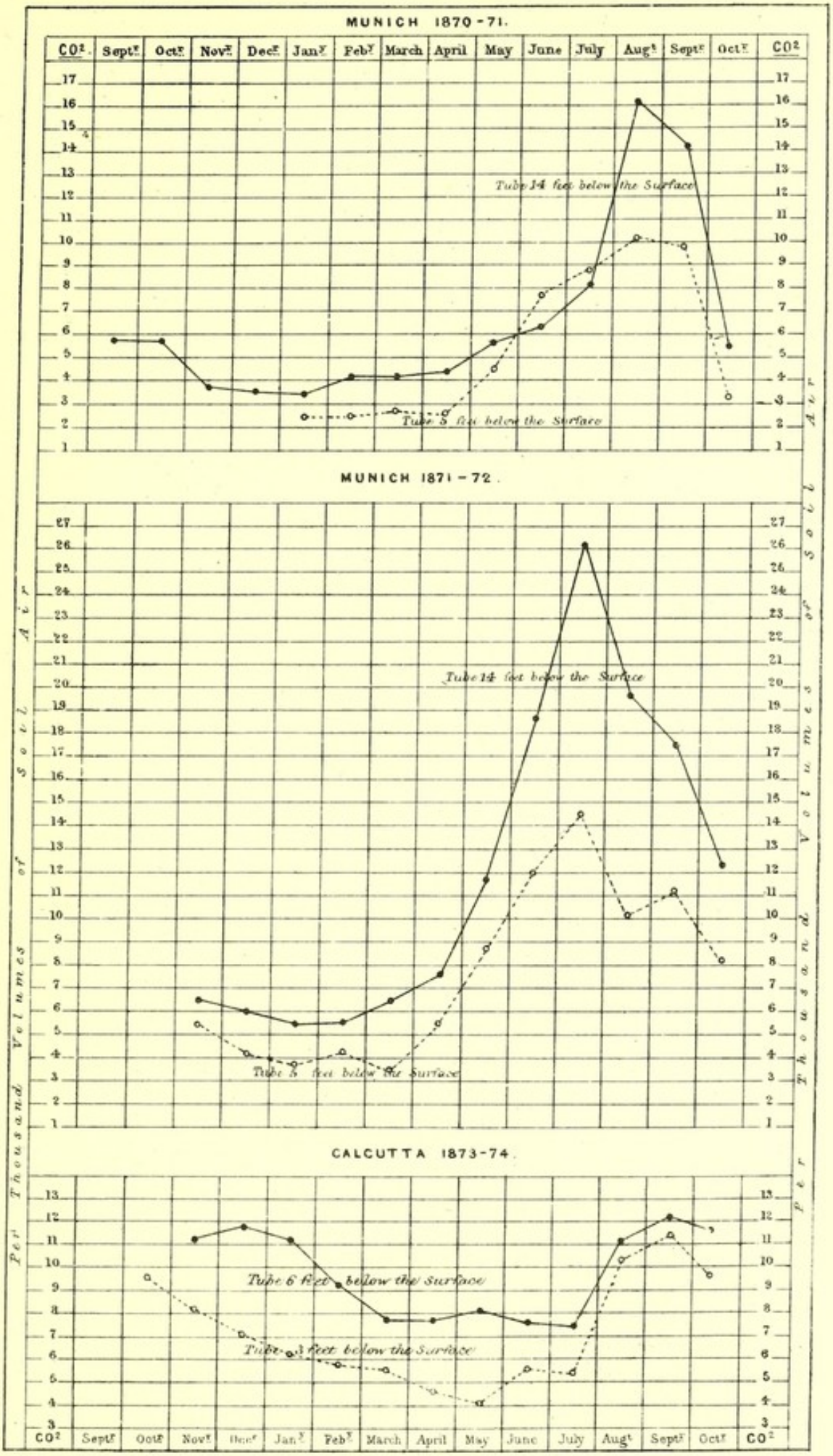
physical conditions is, of course, very imperfect when confined, as in the present instance, to the phenomena of one year. We had hoped to have been able to furnish data regarding the prevalence of disease and the existence of conditions of soil-temperature, water-level, etc., for a longer period, and had indeed drawn up a table showing the monthly figures on these points from February 1872 to August 1874. On coming to examine the statistics of disease in the Returns of the Calcutta Municipality, however, we found such inexplicable discrepancies in the figures contained in two sets of tables prepared in the same office, that we had to abandon the idea. In the meantime, we insert the figures in this table with the exception of those regarding disease. With regard to our other tables and diagrams, it is, of course, necessary that the condition of the mortuary statistics of Calcutta should be taken into consideration in comparing the total mortality and the prevalence of cholera with the data regarding physical facts.

(7.)—General Conclusions regarding the Observations.

It may appear to many that the result of all these observations on conditions of soil is not commensurate with the time and labour expended in obtaining it. In so far as arriving at any definite determination of the influence of soil-conditions on health is concerned, the results as they stand at present are, no doubt not so conclusive as might be desired. It is only on prolonged and continuous observations in various localities that definite conclusions can be based.

Even as it is, however, the determination of the coincidence of prevalence of cholera in Calcutta with the existence of certain marked characteristics in the conditions of the soil is of great importance. It has, no doubt, been known for a long time that the ordinary course of cholera in Calcutta was similar to that shown in this Report, and that the prevalence of the disease was related to local conditions of season; but in regard to this phenomenon, attention has hitherto been almost entirely directed to the conditions of atmospheric meteorology, and this is almost the first attempt which has been made to ascertain whether any definite relations exist between the prevalence of the disease and special telluric phenomena.

We believe that the present observations, although confined to a very limited period, may serve a good purpose in attracting attention in this country to the importance of the subject and to the desirability of obtaining data regarding it. We have, in so far as our own work is concerned, by their means obtained standards of comparison which will be of very great value in examining the conditions of soil present in other localities during the prevalence of special diseases; but it is greatly to be desired that systematic observations of a similar nature should be carried out in various localities throughout the country. Observations from a large number of places are not necessary, and they might readily be conducted at any good meteorological station.



AMOUNT OF CARBONIC ACID AT VARIOUS DEPTHS IN THE SOIL OF MUNICH AND CALCUTTA.

To face p. 196.

CHART II.

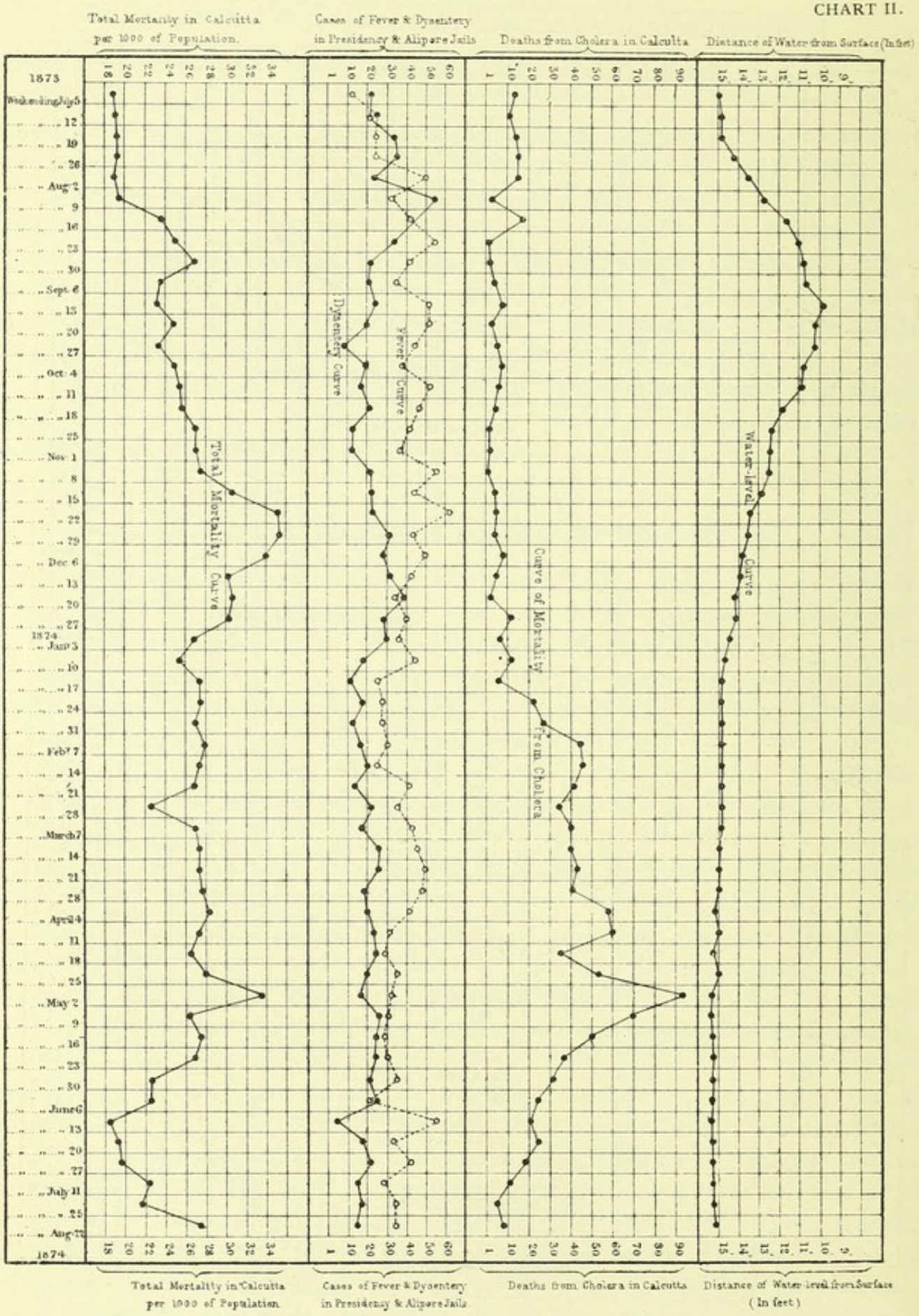

Total Mortality in Calcutta per 1000 of Population.
Cases of Fever & Dysentery in Presidency & Alipore Jails
Deaths from Cholera in Calcutta
Distance of Water from Surface (In feet)
1873
Total Mortality Curve
Dysentery Curve
Fever Curve
Curve of Mortality from Cholera
Water-level Curve
1874
Total Mortality in Calcutta per 1000 of Population
Cases of Fever & Dysentery in Presidency & Alipore Jails
Deaths from Cholera in Calcutta
Distance of Water-level from Surface (In feet)

CHART III.

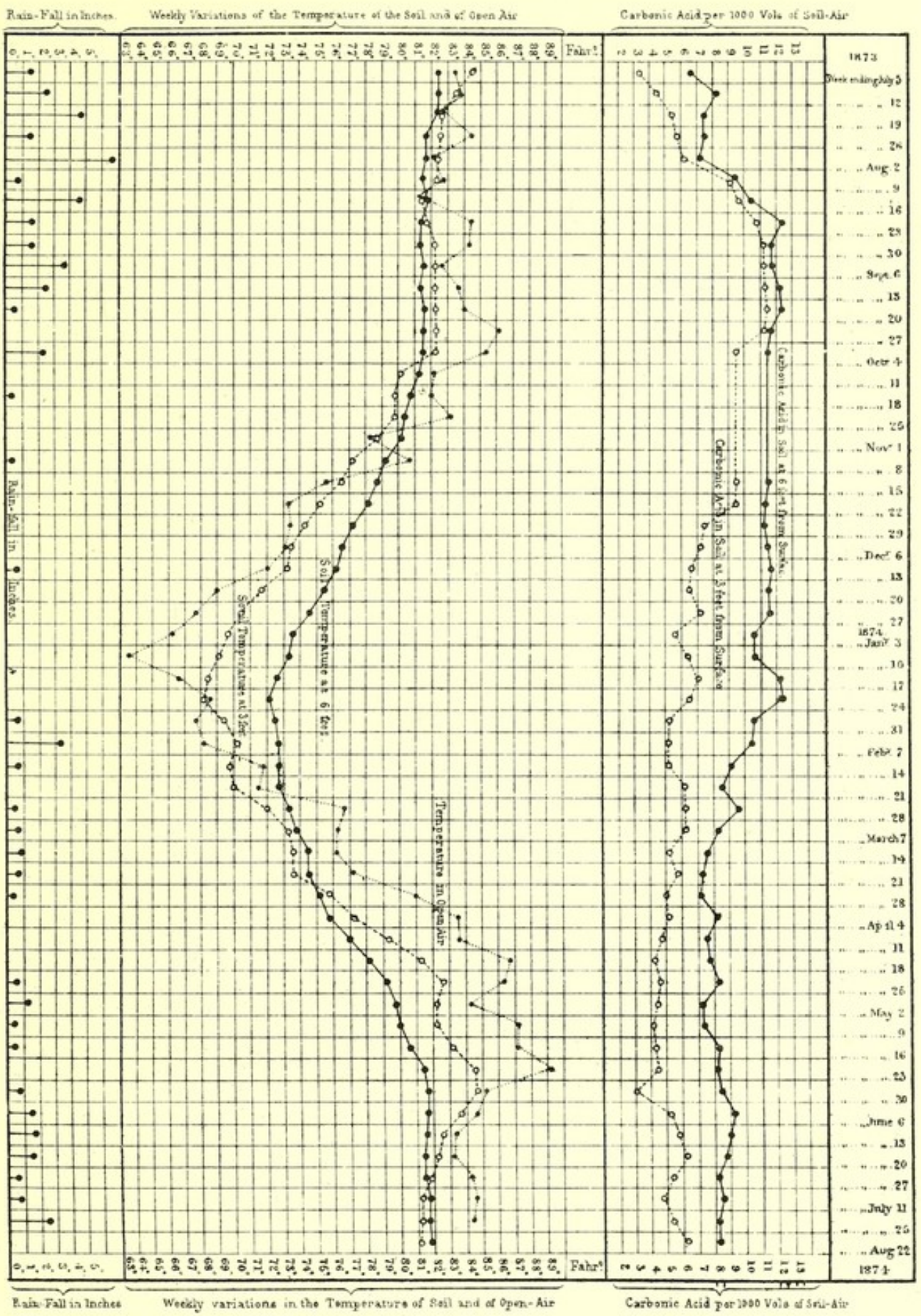
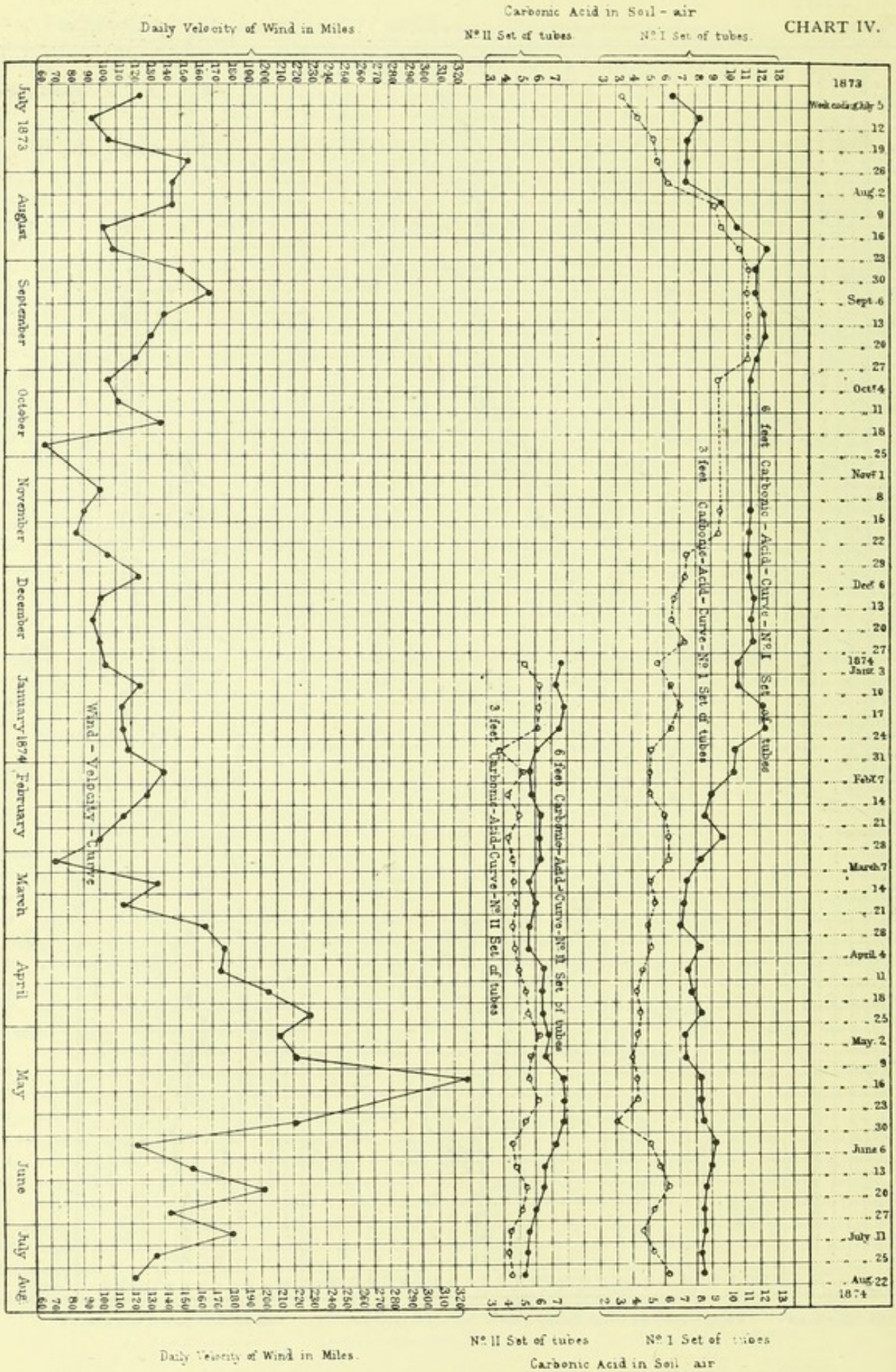

Rain-Fall in Inches.
Weekly Variations of the Temperature of the Soil and of Open Air
Fahr.
Carbonic Acid per 1000 Vols of Soil-Air
1873
Week ending July 5
" " " 12
" " " 19
" " " 26
" " Aug. 2
" " " 9
" " " 16
" " " 23
" " " 30
" " Sept. 6
" " " 13
" " " 20
" " " 27
" " Oct. 4
" " " 11
" " " 18
" " " 25
" " Nov. 1
" " " 8
" " " 15
" " " 22
" " " 29
" " Dec. 6
" " " 13
" " " 20
" " " 27
1874
" " Jan. 3
" " " 10
" " " 17
" " " 24
" " " 31
" " Feb. 7
" " " 14
" " " 21
" " " 28
" " March 7
" " " 14
" " " 21
" " " 28
" " April 4
" " " 11
" " " 18
" " " 25
" " May 2
" " " 9
" " " 16
" " " 23
" " " 30
" " June 6
" " " 13
" " " 20
" " " 27
" " July 11
" " " 25
" " Aug. 22
1874
Soil Temperature at 6 feet
Soil Temperature at 3 feet
Temperature in Open Air
Carbonic Acid in Soil at 6 feet from Surface
Carbonic Acid in Soil at 3 feet from Surface
Rain-Fall in Inches
Fahr.
Rain-Fall in Inches
Weekly variations in the Temperature of Soil and of Open-Air
Carbonic Acid per 1000 Vols of Soil-Air

CHART IV.



THE RELATION OF THE VELOCITY OF THE WIND TO THE AMOUNT OF CARBONIC ACID IN SOIL-AIR.

TABLE I.

Weekly averages of the amount of Carbonic Acid in the Soil; Soil Temperature, etc., in relation to disease—July and August 1873.

Date.	Vols. of Carbonic Acid per 1,000 Vols. of Soil-air.		Temperature of the Soil.				Mean temperature (open air).	Rainfall in inches.	Distance of water-level from surface in feet and inches: weekly averages (at Alipore.)	Weekly returns of deaths from Cholera. (Total reported in Calcutta.)	Weekly returns of sickness from		Weekly returns of deaths from all causes in Calcutta per 1,000 population.
	At 3 feet from surface.	At 6 feet from surface.	At 3 feet from surface.		At 6 feet from surface.						Dysentery. (In Presidency and Alipore Jails.)	Malarious fevers. (In Presidency and Alipore Jails.)	
			Maximum.	Minimum.	Maximum.	Minimum.							
1873			°F.	°F.	°F.	°F.	°F.						
July 1	...	...	...	...	...	...	85·2	0·05"					
" 2	...	...	...	...	...	...	83·7	0·13					
" 3	...	...	84·8	81·8	82·5	81·4	83·0	0·51					
" 4	3·342	7·411	84·8	81·4	82·7	80·8	83·1	0·16					
" 5	3·488	6·394	84·2	81·1	82·6	81·4	81·5	0·42	15' 0"	13	22	12	19·24
" 6	...	...	83·9	81·0	82·7	81·5	83·0	0·04					
" 7	...	...	83·6	80·7	82·5	81·4	83·8	0·35					
" 8	...	...	83·6	80·5	82·5	81·3	83·8	0·42					
" 9	3·923	8·573	83·8	80·7	82·5	81·3	83·5	...					
" 10	5·667	8·664	83·5	80·6	82·7	81·0	84·8	0·41					
" 11	5·522	7·847	84·0	80·4	82·1	81·0	83·3	0·5					
" 12	3·923	7·411	83·5	80·7	82·4	81·0	82·4	1·10	14' 11"	11	22	25	19·76
" 13	4·068	7·266	...	...	...	...	82·8	0·10					
" 14	5·086	7·411	...	...	...	...	81·3	0·19					
" 15	5·667	7·701	82·9	80·4	82·5	80·6	82·6	0·16					
" 16	5·958	7·701	82·5	80·1	82·5	80·6	84·0	1·07					
" 17	5·667	7·266	82·8	80·1	82·9	81·5	84·5	0·48					
" 18	5·667	7·266	...	...	...	...	80·5	1·80					
" 19	6·248	7·701	82·5	80·2	82·5	81·2	83·6	0·31	14' 6"	14	34	27	19·76
" 20	...	...	82·7	80·1	82·0	81·4	85·5	0·07					
" 21	6·380	8·573	82·8	80·1	82·0	81·3	84·2	0·66					
" 22	4·923	7·701	83·1	80·3	81·9	81·6	85·6	...					
" 23	5·376	7·411	82·8	80·4	81·8	81·4	83·4	0·33					
" 24	6·394	6·830	...	...	...	...	83·6	0·38					
" 25	6·248	7·266	82·8	80·2	81·8	81·3	83·9	0·02					
" 26	6·248	7·120	...	...	...	...	85·1	...	14' 2"	15	35	26	19·24
" 27	...	...	82·9	80·3	82·2	81·2	82·4	2·05					
" 28	6·539	7·120	83·5	80·0	81·8	81·2	81·1	3·26					
" 29	6·539	7·556	82·6	80·0	82·2	81·3	81·8	0·73					
" 30	5·958	6·103	82·8	79·8	82·0	81·1	84·4	...					
" 31	5·958	7·701	82·3	79·5	81·8	81·0	83·0	...					
August 1	...	...	82·5	79·6	82·2	81·0	81·8	0·74					
" 2	6·539	7·411	82·0	79·6	81·7	81·0	82·5	0·08	13' 5"	15	23	50	19·24
" 3	...	...	...	...	...	...	83·6	0·13					
" 4	7·266	7·266	...	...	...	...	84·5	0·07					
" 5	9·009	9·155	82·7	79·5	81·9	80·8	82·2	0·11					
" 6	9·300	10·608	82·1	79·6	81·8	81·8	81·2	0·34					
" 7	10·317	10·463	82·3	79·7	81·6	81·0	81·3	0·05					
" 8	9·881	10·027	82·3	79·5	81·7	80·9	82·7	...					
" 9	10·027	9·736	...	...	...	...	83·3	...	12' 9"	4	55	34	19·76
" 10	9·881	9·737	81·9	79·5	82·2	80·5	80·9	0·3					
" 11	9·445	9·591	...	...	...	...	80·2	1·12					
" 12	9·300	9·736	82·2	79·2	81·9	80·6	79·5	1·61					
" 13	9·155	10·608	81·5	79·0	81·6	80·4	80·2	1·27					
" 14	9·881	11·044	81·5	78·8	81·7	80·5	82·1	0·70					
" 15	9·881	11·188	81·6	78·8	81·9	80·3	83·3	0·11					
" 16	10·753	12·206	82·1	78·9	81·8	80·0	84·2	0·07	11' 7"	14	46	44	23·92
" 17	10·027	11·196	81·5	79·0	81·4	80·4	84·9	...					
" 18	...	...	81·8	79·0	81·1	80·4	83·3	0·10					
" 19	10·753	12·061	81·8	79·2	81·5	80·5	84·0	0·93					
" 20	10·899	12·352	81·8	79·1	82·0	80·5	83·9	0·37					
" 21	11·625	13·514	82·0	79·3	82·0	80·5	86·5	...					
" 22	11·770	13·660	81·5	79·5	81·8	80·5	86·0	...					
" 23	10·608	11·916	81·9	79·6	82·1	80·5	83·8	0·04	11' 0"	3	34	55	24·86
" 24	10·608	12·206	81·8	79·6	81·5	80·4	85·3	...					
" 25	11·334	11·770	81·8	79·7	81·3	80·5	86·1	0·14					
" 26	12·642	12·497	82·3	79·7	81·7	80·5	85·5	0·04					
" 27	11·334	12·497	82·1	79·9	81·5	80·6	85·7	...					
" 28	10·753	12·206	82·0	79·4	81·3	80·7	83·2	0·31					
" 29	12·642	12·061	82·3	79·7	81·2	80·8	82·7	0·70					
" 30	11·044	10·463	82·7	79·7	81·2	80·8	83·0	0·40	10' 8"	4	23	41	27·04
" 31	...	...	...	...	...	...	84·3	0·48					

TABLE II.

Weekly averages of the amount of Carbonic Acid in the Soil; Soil Temperature, etc., in relation to disease—September and October 1873.

Date.	Vols. of Carbonic Acid per 1,000 Vols. of Soil-air.		Temperature of the Soil.				Mean temperature (open air).	Rainfall in inches.	Distance of water-level from surface in feet and inches; weekly averages (at Alipore).	Weekly Returns of deaths from Cholera. (Total reported in Calcutta.)	Weekly Returns of sickness from		Weekly Returns of deaths from all causes in Calcutta per 1,000 of population.
			At 3 feet from surface.		At 6 feet from surface.								
	At 3 feet from surface.	At 6 feet from surface.	Maximum.	Minimum.	Maximum.	Minimum.					Dysentery. (In Presidency and Alipore Jails.)	Malarious fevers. (In Presidency and Alipore Jails.)	
1873.			° F.	° F.	° F.	° F.	° F.						
September 1 ...	11·189	11·770	82·5	79·8	81·4	80·8	83·9	0·09					
„ 2 ...	10·899	12·352	81·8	79·8	81·4	80·9	83·0	0·10					
„ 3 ...	10·608	12·206	82·5	79·8	81·3	80·7	84·0						
„ 4 ...	10·899	11·916	81·8	79·8	82·1	80·5	83·4	0·11					
„ 5 ...	10·753	11·916	82·3	79·8	81·6	80·1	82·7	0·70					
„ 6 ...	11·916	11·625	82·6	79·8	81·5	80·1	78·6	2·32	10′ 5″	5	22	37	23·40
„ 7 ...	11·480	12·352	82·5	79·5	81·4	80·7	82·0	0·19					
„ 8 ...	10·899	12·061	82·1	79·4	81·3	80·4	85·0						
„ 9 ...	...	...	81·8	79·6	81·5	80·4	86·0						
„ 10 ...	11·625	12·061	82·5	79·8	81·5	80·5	85·0	0·29					
„ 11 ...	11·625	12·497	82·3	79·9	81·3	80·7	84·6	0·29					
„ 12 ...	...	...	82·2	80·0	81·2	80·8	82·1	0·72					
„ 13 ...	11·044	12·206	82·7	80·0	81·7	80·9	81·7	0·75	9′ 9″	9	25	52	23·40
„ 14 ...	...	...	...	...	...	...	81·3	0·13					
„ 15 ...	11·334	11·916	...	...	...	...	83·5	0·15					
„ 16 ...	11·625	12·497	82·5	79·8	81·7	80·6	84·9	0·06					
„ 17 ...	11·480	12·642	81·8	79·9	81·4	80·8	84·0						
„ 18 ...	10·899	...	81·8	80·0	81·7	80·5	84·6						
„ 19 ...	11·770	12·352	82·2	81·7	81·3	80·5	84·8						
„ 20 ...	11·770	12·788	81·9	80·1	81·4	80·6	85·0	...	10′ 1″	4	20	51	24·96
„ 21 ...	...	...	...	...	...	...	86·1						
„ 22 ...	12·061	12·788	82·8	80·1	81·5	81·0	86·6						
„ 23 ...	11·916	11·625	82·2	80·1	81·5	80·7	86·8						
„ 24 ...	12·206	12·788	...	...	...	...	87·0						
„ 25 ...	11·334	12·061	82·2	80·3	81·5	81·0	83·7						
„ 26 ...	10·753	10·899	82·2	80·4	81·6	80·9	85·8						
„ 27 ...	10·463	11·334	82·3	80·4	81·4	80·9	86·6	...	10′ 3″	6	8	45	23·92
„ 28 ...			82·2	80·5	81·4	80·6	86·5						
„ 29 ...			82·6	80·6	81·5	80·9	86·6						
„ 30 ...			...	...	....	...	84·6						
October 1 ...			82·3	80·3	81·6	80·9	84·9						
„ 2 ...			82·3	80·5	81·6	81·0	84·8						
„ 3 ...			82·5	80·0	81·5	81·0	85·7	2·05					
„ 4 ...			81·8	78·1	81·4	80·8	83·9	...	10′ 8″	8	20	38	27·56
„ 5 ...			...	...	...	...	84·4						
„ 6 ...			81·7	79·5	81·4	80·9	82·6						
„ 7 ...			...	...	...	...	82·1						
„ 8 ...			81·7	78·9	81·3	80·6	81··						
„ 9 ...			80·5	78·4	81·4	80·3	81·5						
„ 10 ...			79·9	78·3	81·2	80·2	82·6						
„ 11 ...			80·0	78·2	81·0	80·2	79·4	0·20	10′ 11″	6	16	53	24·96
„ 12 ...			80·1	78·1	80·9	80·1	80·4	0·07					
„ 13 ...			80·1	77·9	80·8	80·0	80·9	0·08					
„ 14 ...	9·685	11·705	...	...	...	...	81·2						
„ 15 ...			80·1	77·9	80·8	79·9	82·3						
„ 16 ...			79·5	77·8	80·7	79·9	82·9						
„ 17 ...			79·7	77·8	80·8	79·8	82·6						
„ 18 ...			79·8	77·8	80·5	79·8	83·5	...	11′ 9″	5	22	47	25·67
„ 19 ...			...	...	...	...	83·7						
„ 20 ...			79·8	77·9	80·5	79·6	84·3						
„ 21 ...			...	...	...	...	84·6						
„ 22 ...			79·6	77·9	80·5	79·8	83·8						
„ 23 ...			...	...	...	...	81·8						
„ 24 ...			79·6	78·0	80·4	79·6	81·9						
„ 25 ...			80·1	78·0	80·4	79·0	82·0	...	12′ 3″	4	14	42	27·04
„ 26 ...			79·4	78·0	80·3	79·0	80·4						
„ 27 ...			79·8	78·0	80·8	79·3	80·6						
„ 28 ...			78·9	77·8	80·1	79·0	77·5						
„ 29 ...			78·6	77·4	80·1	79·1	77·8						
„ 30 ...			78·3	77·0	79·9	79·0	78·3						
„ 31 ...			77·7	76·5	79·8	78·7	77·8						

TABLE III.

Weekly averages of the amount of Carbonic Acid in the Soil; Soil Temperature, etc., in relation to disease—November and December 1873.

Date.	Vols. of Carbonic Acid per 1,000 Vols. of Soil-air.		Temperature of the Soil.				Mean temperature (open air).	Rainfall in inches.	Distance of water-level from surface in feet and inches: weekly averages (at Alipore).	Weekly Returns of deaths from Cholera. (Total reported in Calcutta.)	Weekly Returns of sickness from		Weekly Returns of deaths from all causes in Calcutta per 1,000 of population.
			At 3 feet from surface.		At 6 feet from surface.						Dysentery. (In Presidency and Alipore Jails.)	Malarious fevers. (In Presidency and Alipore Jails.)	
	At 3 feet from surface.	At 6 feet from surface.	Maximum.	Minimum.	Maximum.	Minimum.							
1873.			° F.	° F.	° F.	° F.	° F.						
November 1 ...			77·5	75·8	79·6	78·8	76·2	...	12′ 4″	4	13	38	27·04
„ 2 ...			77·2	75·2	79·4	78·2	78·2						
„ 3 ...			76·5	74·7	79·1	78·0	78·1	0·01					
„ 4 ...			76·6	74·9	79·2	78·0	80·8						
„ 5 ...			76·9	75·0	78·9	78·0	82·0						
„ 6 ...			77·2	75·4	79·5	78·1	82·5						
„ 7 ...			77·6	75·7	79·5	78·1	82·6						
„ 8 ...			77·8	76·1	79·1	78·0	81·4	...	12′ 4″	2	21	56	27·56
„ 9 ...			...	...	...	...	79·2						
„ 10 ...	9·685	11·705	77·8	76·2	79·1	78·0	75·8						
„ 11 ...			77·6	75·7	79·1	77·9	73·9						
„ 12 ...			77·1	75·0	79·2	77·8	74·3						
„ 13 ...			76·5	74·5	78·7	77·5	74·9						
„ 14 ...			75·8	74·1	78·7	77·5	75·3						
„ 15 ...			75·5	73·8	78·6	77·1	76·2	...	12′ 11″	5	22	45	30·9
„ 16 ...			75·6	73·9	78·3	77·1	74·5						
„ 17 ...			75·2	73·7	77·5	77·0	74·3						
„ 18 ...			75·4	73·3	78·1	76·9	72·9						
„ 19 ...			75·7	73·0	78·5	76·8	74·0						
„ 20 ...			75·6	72·8	78·6	76·8	73·5						
„ 21 ...	10·172	11·480	74·5	72·8	77·8	76·5	73·0						
„ 22 ..	8·719	10·899	...	...	...	...	73·0	...	13′ 4″	5	24	63	35·88
„ 23 ...	8·137	10·608	74·3	72·4	77·6	76·0	72·6						
„ 24 ...	7·556	9·881	74·5	72·5	77·3	75·9	74·2						
„ 25 ...	7·120	10·172	74·5	72·2	77·4	75·0	74·5						
„ 26 ...	7·120	11·625	74·1	72·3	77·5	75·4	75·0						
„ 27 ...	7·556	12·788	74·2	72·4	77·1	75·7	73·7						
„ 28 ...	7·847	11·625	74·5	72·2	77·3	75·5	71·9						
„ 29 ...	7·266	11·625	74·5	70·4	77·1	75·5	69·4	...	13′ 5″	5	31	44	35·88
„ 30 ...	7·556	11·625	73·7	72·0	76·8	75·0	69·0						
December 1 ...	6·975	11·770	73·8	71·5	76·8	75·0	73·1						
„ 2 ...	7·266	12·206	73·5	71·6	76·7	75·1	74·4						
„ 3. ...	6·975	11·916	73·6	71·7	76·9	75·0	73·9						
„ 4 ...	7·120	11·625	73·7	71·9	76·5	74·8	72·8						
„ 5 ...	6·975	11·916	73·8	71·8	76·8	74·9	71·9						
„ 6 ...	7·411	11·480	73·8	71·8	76·6	74·9	71·8	...	13′ 8″	9	28	50	34·84
„ 7 ...	...	...	73·5	71·5	76·5	74·5	72·8						
„ 8 ...	6·539	12·206	73·5	71·5	76·5	74·6	71·0						
„ 9 ...	6·830	12·061	73·7	71·4	76·1	74·5	71·8						
„ 10 ...	6·830	11·770	73·5	71·0	76·1	74·6	72·7						
„ 11 ...	6·975	11·916	73·2	71·1	75·0	74·6	72·3	>82					
„ 12 ...	6·975	11·770	73·1	71·5	76·1	74·5	73·8						
„ 13 ...	7·120	11·334	73·1	71·3	76·0	73·9	69·9	...	13′ 10″	5	32	42	30·16
„ 14 ..	...	...	73·1	71·0	75·8	74·2	68·4						
„ 15 ...	6·830	11·916	72·5	70·5	75·8	74·0	68·7						
„ 16 ...	7·120	11·625	72·1	69·9	75·7	73·9	69·7						
„ 17 ...	6·539	11·334	71·8	69·8	75·6	73·4	69·6						
„ 18 ...	...	...	71·3	69·4	75·5	73·5	69·6						
„ 19 ...	6·975	11·334	71·3	69·2	75·5	73·5	69·3						
„ 20 ...	...	...	71·3	69·0	75·1	73·5	69·4	...	14′ 2″	3	39	34	30·9
„ 21 ...	6·975	11·625	70·8	68·9	75·1	73·0	69·1						
„ 22 ...	7·120	12·261	...	...	...	...	67·5						
„ 23 ...	6·975	12·061	70·7	68·8	74·9	73·0	68·0						
„ 24 ...	7·266	11·770	70·6	68·4	74·9	72·8	67·8						
„ 25 ...	...	...	70·7	68·2	74·8	72·8	66·9						
„ 26 ...	...	...	70·1	68·2	74·5	72·6	67·6						
„ 27 ...	7·701	11·770	70·1	67·9	74·4	72·6	68·1	...	14′ 1″	12	28	40	30·16
„ 28 ...	...	...	69·6	68·0	74·3	72·5	69·8						
„ 29 ...	...	...	70·7	68·0	74·1	72·1	67·3						
„ 30 ...	7·266	10·753	69·9	68·1	74·3	72·0	63·9						
„ 31 ...	...	...	70·1	68·0	74·0	72·0	63·4						

TABLE IV.

Weekly averages of the amount of Carbonic Acid in the Soil; Soil Temperature, etc., in relation to disease—January and February 1874.

Date.	Vols. of Carbonic Acid per 1,000 Vols. of Soil-air (estimated in two localities, Nos. 1 & 2)				Temperature of the Soil.				Mean temperature (open air).	Rainfall in inches.	Distance of water-level from surface in feet and inches: weekly averages (at Alipore).	Prevalence of various Diseases.			
	No. 1.		No. 2.		At 3 feet from surface.		At 6 feet from surface.					Weekly Returns of deaths from Cholera. (Total reported in Calcutta.)	Weekly Returns of sickness in the Presidency and Alipore Jails from		Weekly Returns of deaths from all causes per 1,000 of population in Calcutta.
	3 feet from surface.	6 feet from surface.	3 feet from surface.	6 feet from surface.	Maximum.	Minimum.	Maximum.	Minimum.					Dysentery.	Malarious fevers.	
1874					°F.	°F.	°F.	°F.	°F.						
Jan. 1	5·736	10·608	...	...	...	...	...	...	61·4						
„ 2	...	...	5·376	7·701	70·2	67·4	73·8	71·9	67·1						
„ 3	...	10·899	—	...	69·6	67·3	73·7	71·9	69·9	...	14′ 4″	7	30	36	27·04
„ 4	...	...	...	...	69·6	67·4	74·0	71·8	68·2						
„ 5	...	...	6·539	7·847	69·7	67·8	73·8	71·5	64·5						
„ 6	6·394	10·172	...	...	69·5	67·5	73·5	71·3	61·9						
„ 7	...	...	5·958	7·120	69·5	68·8	73·2	70·5	61·0						
„ 8	6·103	10·899	...	...	68·8	66·3	73·4	70·8	61·7						
„ 9	...	...	6·394	7·120	68·2	66·0	72·8	70·7	62·3						
„ 10	6·884	11·044	...	...	67·7	65·6	72·7	70·2	65·3	...	14′ 6″	11	18	46	25·67
„ 11	...	...	...	...	68·2	65·5	72·7	70·0	69·0						
„ 12	...	...	6·830	7·701	68·9	65·7	72·7	70·5	71·9						
„ 13	7·411	12·206	...	...	68·2	66·0	72·9	70·7	68·2						
„ 14	...	...	6·103	7·847	68·9	66·6	72·8	70·5	61·4						
„ 15	6·975	12·061	...	...	...	...	...	...	61·0						
„ 16	...	...	6·394	8·283	68·2	65·5	72·7	69·8	63·3						
„ 17	6·684	12·206	...	..	68·3	65·2	72·4	69·5	65·9	...	14′ 9″	6	12	27	27·56
„ 18	...	...	6·539	7·701	68·1	65·5	72·1	70·0	65·2						
„ 19	6·394	12·061	...	...	67·9	65·7	72·5	69·9	66·6						
„ 20	...	...	5·812	7·847	67·5	65·4	72·1	69·4	64·6						
„ 21	6·684	12·206	...	...	67·8	65·6	71·9	69·4	67·4						
„ 22	...	...	5·958	7·266	67·7	65·4	72·1	69·9	69·9						
„ 23	6·539	12·642	...	...	67·8	65·9	72·1	69·8	72·5						
„ 24	...	...	5·958	7·701	68·9	66·4	72·5	69·6	72·3	...	14′ 9″	23	18	29	27·54
„ 25	...	...	...	...	69·7	67·6	72·6	70·0	63·6	0·49					
„ 26	5·376	11·044	4·359	6·248	69·5	67·6	72·8	70·0	64·8						
„ 27	5·086	10·608	...	...	69·8	67·1	72·7	70·0	65·4						
„ 28	...	...	3·342	5·812	70·8	66·8	72·7	69·9	66·9						
„ 29	4·940	10·317	...	...	68·7	66·5	72·7	69·8	69·7						
„ 30	...	...	...	...	68·7	66·4	72·6	70·0	71·8						
„ 31	...	10·463	...	6·248	69·3	66·5	72·8	70·0	73·1	...	14′ 10″	27	13	28	27·04
Feb. 1	...	...	...	...	69·8	67·4	72·8	70·0	68·2	0·80					
„ 2	4·650	10·463	6·830	4·068	70·0	68·0	72·8	70·0	70·0	0·15					
„ 3	...	...	...	...	70·3	68·5	72·8	70·3	71·0						
„ 4	5·376	10·463	4·650	5·958	70·1	68·1	72·7	70·1	70·5						
„ 5	...	...	...	...	69·8	67·9	73·1	70·2	67·4	2·01					
„ 6	5·522	10·463	...	...	70·2	67·7	72·8	70·3	64·8	0·16					
„ 7	...	...	4·214	6·539	70·6	67·4	73·0	70·0	66·1	...	14′ 10″	46	18	30	28·00
„ 8	...	...	...	...	69·8	67·0	72·9	70·0	66·4						
„ 9	...	10·027	...	...	69·4	66·6	72·9	70·0	68·2						
„ 10	...	...	3·342	6·103	68·8	66·8	72·5	69·8	7·4						
„ 11	4·940	10·027	...	...	68·9	67·3	72·8	70·0	76·5						
„ 12	...	...	...	...	69·8	68·4	72·8	70·0	77·3						
„ 13	5·231	7·411	...	...	71·2	68·8	72·8	70·3	71·1						
„ 14	...	...	4·940	5·522	71·5	68·1	72·8	70·5	71·2	0·63	14′ 10″	47	21	25	27·58
„ 15	6·103	8·719	...	...	...	...	...	...	66·3						
„ 16	...	...	4·795	6·684	70·7	68·1	72·8	70·0	66·7						
„ 17	6·539	7·992	...	...	70·4	67·4	72·7	70·0	68·8						
„ 18	...	...	5·086	6·103	69·4	66·7	72·6	69·8	71·1						
„ 19	...	8·373	...	...	69·4	67·0	72·8	70·0	74·6						
„ 20	...	...	5·231	6·103	69·6	67·0	72·8	70·1	75·5						
„ 21	5·522	9·736	...	...	70·3	67·7	73·2	70·1	78·0	...	14′ 10″	43	16	41	27·04
„ 22	...	...	...	...	71·2	68·3	73·2	70·2	78·2						
„ 23	...	...	4·504	6·248	71·5	69·0	73·5	70·6	76·5						
„ 24	6·394	8·573	...	...	72·0	69·8	73·4	70·6	75·0						
„ 25	...	...	...	5·376	71·8	70·0	73·1	70·7	77·2						
„ 26	6·103	9·591	...	...	71·9	70·2	73·5	70·9	77·4	0·02					
„ 27	...	...	4·214	7·120	72·8	70·2	73·5	70·9	77·4						
„ 28	...	...	...	...	72·5	70·3	73·5	71·1	75·9	...	14′ 10″	37	23	37	22·54

TABLE V.

Weekly averages of the amount of Carbonic Acid in the Soil; Soil Temperature, etc., in relation to disease—March and April 1874.

Date.	Vols. of Carbonic Acid per 1,000 vols. of Soil-air (estimated in two localities, Nos. 1 and 2).				Temperature of the Soil.				Mean temperature (open air).	Rainfall in inches.	Distance of water-level from surface in feet and inches: weekly averages (at Alipore).	Prevalence of various Diseases.			
	No. 1.		No. 2.		At 3 feet from surface.		At 6 feet from surface.					Weekly Returns of deaths from Cholera. (Total reported in Calcutta.)	Weekly Returns of sickness in the Presidency and Alipore Jails from		Weekly Returns of deaths from all causes per 1,000 of population in Calcutta.
	3 feet from surface.	6 feet from surface.	3 feet from surface.	6 feet from surface.	Maximum.	Minimum.	Maximum.	Minimum.					Dysentery.	Malarious fevers.	
1874.					°F.	°F.	°F.	°F.	°F.						
March 1	6·539	8·137	...	...	72·5	70·6	73·8	70·7	74·5						
„ 2	...	...	4·650	5·958	72·3	70·7	73·8	71·0	75·8						
„ 3	6·394	...	...	...	73·1	70·5	73·6	71·0	76·7						
„ 4	...	...	4·795	6·830	...	...	...	...	78·2						
„ 5	5·958	8·428	...	...	73·8	70·5	74·1	71·0	76·7						
„ 6	...	...	4·795	5·958	73·7	71·3	74·0	71·0	75·2						
„ 7	6·394	8·428	...	...	73·8	71·7	74·2	71·5	76·7	0·41	14′ 10″	40·	18	41	20·04
„ 8	...	...	...	...	...	...	...	...	75·5	0·78					
„ 9	...	...	4·214	5·667	73·3	68·7	74·2	71·2	78·3						
„ 10	4·940	6·539	...	...	73·9	71·4	74·5	71·8	79·0	0·09					
„ 11	...	...	4·650	5·812	73·7	72·4	74·3	71·4	76·3						
„ 12	4·650	8·573	...	...	73·8	72·1	74·6	71·6	74·0						
„ 13	...	...	5·376	5·667	73·9	71·5	74·8	71·6	74·1						
„ 14	5·667	8·137	...	...	73·4	71·1	74·8	71·5	76·8		14′ 11″	38	26	46	27·56
„ 15	...	...	...	...	73·4	71·0	74·3	71·8	79·8						
„ 16	...	...	4·940	6·103	...	...	...	...	72·8	0·40					
„ 17	5·231	6·539	...	...	73·8	71·0	74·7	72·0	74·6	0·10					
„ 18	...	...	4·940	5·958	...	...	...	...	78·7						
„ 19	5·959	7·266	...	...	...	...	...	...	78·0						
„ 20	...	...	5·086	6·103	73·7	71·6	74·7	71·8	77·2						
„ 21	6·684	8·283	...	...	73·7	71·9	74·7	72·0	78·6		15′ 0″	44	26	50	27·04
„ 22	...	...	...	...	...	...	...	...	79·0						
„ 23	...	...	4·940	5·958	...	...	...	...	79·6						
„ 24	...	...	...	...	75·3	72·7	74·9	72·1	81·5	0·16					
„ 25	5·086	6·830	...	...	75·7	73·1	75·1	72·4	82·7						
„ 26	...	...	4·359	5·667	75·8	73·6	75·0	72·6	81·8						
„ 27	...	...	...	...	76·3	74·0	75·2	75·1	81·8						
„ 28	4·940	7·556	...	...	76·6	74·4	75·2	72·9	80·5		15′ 0″	40	18	49	27·58
„ 29	...	...	...	...	76·8	74·7	75·5	72·8	81·9						
„ 30	...	...	5·086	5·667	76·4	74·5	75·7	73·0	83·6						
„ 31	5·376	8·283	...	...	77·1	74·9	75·9	73·1	84·0						
April 1	...	...	4·795	5·958	77·5	75·2	75·8	73·3	84·5						
„ 2	4·940	7·992	...	...	77·6	75·1	76·1	73·5	84·3						
„ 3	...	...	4·795	5·812	77·7	76·1	76·2	73·5	82·6						
„ 4	...	...	...	...	78·5	76·0	76·5	74·0	84·6		15′ 1″	58	20	41	28·62
„ 5	5·086	7·992	...	...	79·2	76·7	76·3	74·0	83·8						
„ 6	...	...	4·940	6·394	78·7	77·1	76·8	74·0	82·8						
„ 7	...	...	...	...	79·1	76·8	76·8	74·2	82·5						
„ 8	4·940	7·847	...	...	79·7	76·8	77·0	74·7	82·4						
„ 9	...	...	...	...	79·3	77·2	77·1	74·3	83·7						
„ 10	...	...	5·231	6·684	79·3	77·4	77·3	74·8	84·7						
„ 11	4·795	7·256	...	...	79·7	78·0	77·5	75·0	86·7		15′ 0″	60	25	30	27·55
„ 12	...	...	...	...	79·8	78·2	78·0	75·1	88·3						
„ 13	...	...	...	...	80·8	78·3	78·1	75·0	86·8						
„ 14	...	...	...	...	81·5	79·0	77·9	75·2	87·4						
„ 15	...	...	5·231	6·103	81·9	79·0	78·2	75·5	86·2						
„ 16	4·504	7·847	...	...	81·8	79·5	78·1	75·9	85·6						
„ 17	...	...	5·522	6·830	81·7	79·5	78·7	76·0	86·7						
„ 18	4·214	7·992	...	...	81·9	79·7	78·5	76·0	87·1		15′ 2″	36	28	29	26·52
„ 19	...	...	...	...	...	...	...	...	86·4						
„ 20	...	...	...	...	82·3	80·0	79·0	76·0	86·2						
„ 21	...	...	...	...	82·6	80·2	79·0	76·2	85·8						
„ 22	...	...	5·522	5·812	82·5	80·3	79·1	76·7	87·3						
„ 23	4·940	8·283	...	...	82·9	80·7	79·2	76·9	87·5						
„ 24	...	...	...	...	82·8	80·9	79·5	77·0	84·8	0·20					
„ 25	...	...	5·812	6·830	82·8	80·9	79·5	77·0	87·5		15′ 1″	54	21	37	28·08
„ 26	...	...	...	...	...	...	...	...	85·3						
„ 27	...	...	...	...	82·7	80·8	79·2	77·1	84·3	0·25					
„ 28	...	...	...	...	82·8	80·8	79·8	77·2	80·8	0·21					
„ 29	4·795	6·830	...	...	81·9	80·3	79·9	77·5	84·3						
„ 30	...	...	6·103	6·830	81·9	79·8	79·8	77·4	82·8	0·81					

TABLE VI.

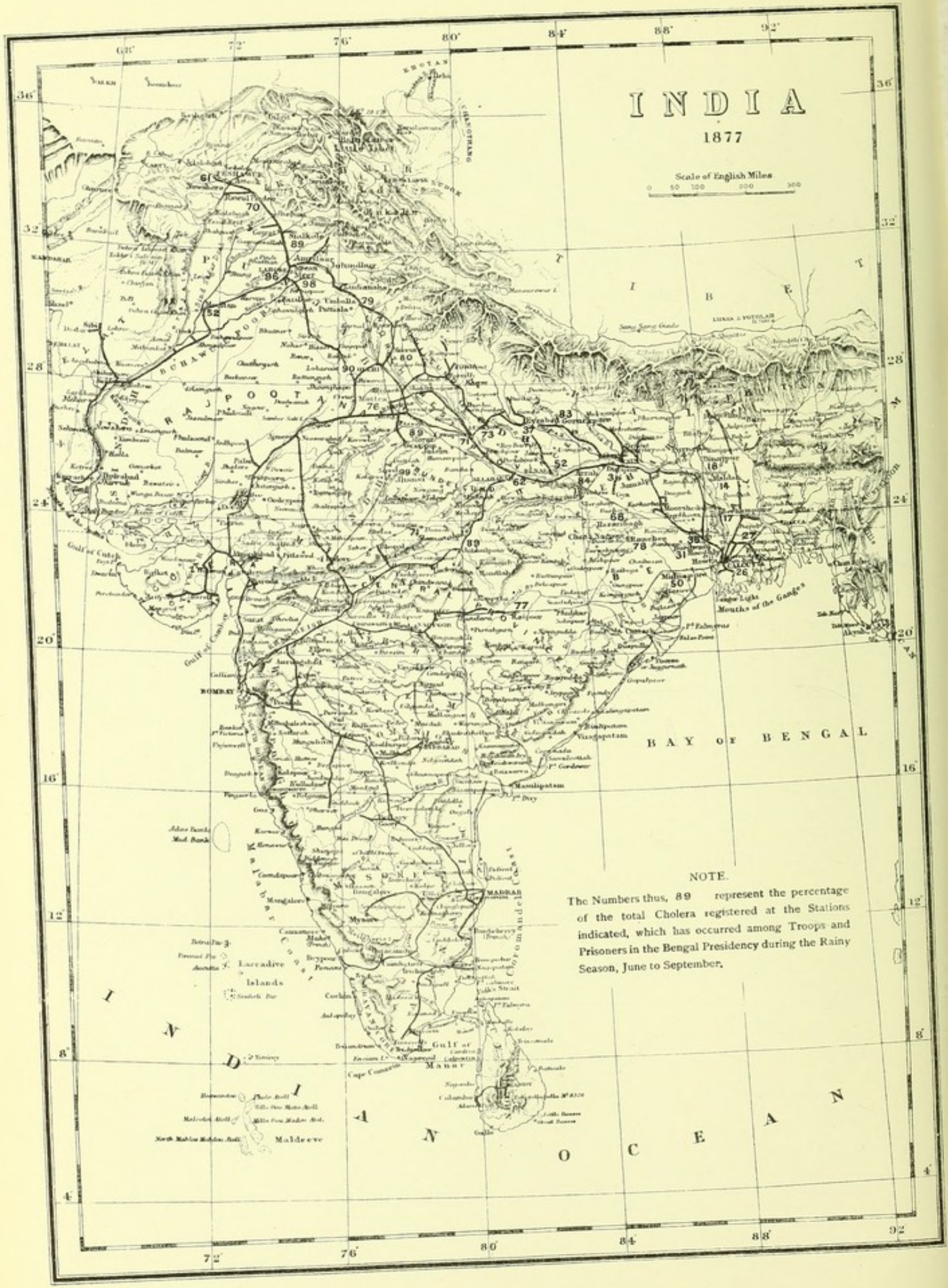
Weekly averages of the amount of Carbonic Acid in the Soil; Soil Temperature, etc., in relation to disease—May and June 1874.

Date.	Vols. of Carbonic Acid per 1,000 Vols. of Soil-air (estimated in two localities, Nos. 1 and 2).				Temperature of the Soil.				Mean temperature (open air).	Rainfall in inches.	Distance of water-level from surface in feet and inches; weekly averages (at Alipore).	Prevalence of various Diseases.			
	No. 1.		No. 2.		At 3 feet from surface.		At 6 feet from surface.					Weekly returns of deaths from Cholera. (Total reported in Calcutta.)	Weekly Returns of sickness in the Presidency and Alipore Jails from		Weekly Returns of deaths from all causes per 1,000 of population in Calcutta.
	3 feet from surface.	6 feet from surface.	3 feet from surface.	6 feet from surface.	Maximum.	Minimum.	Maximum.	Minimum.					Dysentery.	Malarious fevers.	
1874.					° *F.*	° *F.*	° *F.*	° *F.*	° *F.*						
May 1	4·504	8·137	...	...	81·9	79·4	79·9	77·5	82·9						
„ 2	...	...	...	...	81·5	79·2	79·9	77·5	89·9		15′ 2″	93	18	33	33·80
„ 3	...	...	...	...	81·3	79·4	79·9	77·6	87·3						
„ 4	...	...	...	...	81·8	79·7	79·9	77·8	86·0						
„ 5	...	...	...	...	81·8	79·9	80·0	77·6	86·9						
„ 6	...	...	5·958	6·539	81·9	80·1	80·1	77·5	87·0						
„ 7	4·068	7·411	...	...	...	...	...	...	87·8						
„ 8	...	...	...	...	82·5	80·1	80·1	77·9	88·4						
„ 9	...	...	...	...	83·0	80·3	80·2	77·6	87·2	0·08	15′ 2″	70	28	30	26·52
„ 10	...	...	...	...	82·8	81·0	80·5	77·7	86·6						
„ 11	...	...	...	...	82·8	81·2	80·5	78·0	88·4	0·04					
„ 12	...	...	...	...	82·8	81·3	80·4	78·1	88·6	0·08					
„ 13	...	...	5·812	7·556	82·9	81·5	80·9	78·1	83·4						
„ 14	4·359	8·428	...	...	84·9	81·2	80·5	78·3	86·6						
„ 15	...	...	5·812	7·701	83·3	81·2	80·6	78·5	87·8						
„ 16	...	...	...	...	83·4	81·4	80·8	78·5	89·1		15′ 2″	50	26	28	27·56
„ 17	...	...	...	...	83·5	81·7	81·0	78·5	89·3						
„ 18	4·504	8·283	...	...	83·8	82·0	81·1	78·5	89·6						
„ 19	...	...	...	...	84·2	82·0	81·1	78·9	90·2						
„ 20	...	...	...	...	84·9	82·7	81·3	78·9	89·2						
„ 21	...	...	6·103	7·992	84·9	83·0	81·6	79·0	90·0						
„ 22	...	...	...	...	84·8	83·1	81·9	79·0	89·6						
„ 23	...	...	...	...	85·1	83·3	81·9	79·0	88·2		15′ 2″	37	26	30	27·04
„ 24	...	...	...	...	...	...	...	...	87·4						
„ 25	...	...	...	...	84·9	83·3	81·5	79·6	86·2	0·04					
„ 26	3·051	8·428	...	...	84·9	83·2	81·5	79·6	83·7	0·85					
„ 27	...	...	5·376	7·847	85·1	82·7	81·8	79·4	86·6						
„ 28	...	...	...	...	84·8	82·0	81·8	79·5	84·2						
„ 29	...	...	...	...	84·7	82·0	81·9	79·5	85·5						
„ 30	...	...	...	...	83·5	81·7	82·0	79·5	84·0	0·07	15′ 2″	32	20	37	22·88
„ 31	...	...	...	...	83·3	81·6	81·8	79·5	86·3						
June 1	5·376	9·300	...	...	83·8	81·5	81·9	79·4	87·8						
„ 2	...	...	5·667	7·411	83·3	81·4	81·7	79·4	86·6	0·02					
„ 3	...	...	...	...	83·9	81·8	81·7	79·4	85·2	0·27					
„ 4	...	...	...	...	84·5	82·0	81·8	79·4	81·9	0·02					
„ 5	5·522	9·009	...	...	84·8	81·5	82·0	79·5	84·2	0·08					
„ 6	...	...	3·778	7·120	...	...	...	...	81·2	1·17	15′ 2″	27	24	22	22·4
„ 7	...	...	...	...	83·5	80·9	81·8	79·3	82·5	0·06					
„ 8	...	...	...	...	82·5	80·5	81·9	79·0	81·8	0·08					
„ 9	5·812	9·009	...	...	82·5	80·4	81·9	79·0	82·5	0·12					
„ 10	...	...	...	...	82·1	80·2	81·2	79·0	80·7	1·47					
„ 11	...	...	...	...	81·9	80·0	81·5	79·0	83·7						
„ 12	...	...	4·940	6·539	...	...	...	...	85·8	0·05					
„ 13	...	...	...	...	81·8	80·0	81·7	79·0	86·9		15′ 2″	20	5	57	18·72
„ 14	...	...	...	...	82·1	80·1	81·5	79·0	85·4	0·58					
„ 15	6·103	8·864	...	...	82·8	80·2	81·2	79·0	83·3	0·03					
„ 16	...	...	...	...	82·9	80·1	81·7	79·0	84·1	0·14					
„ 17	...	...	...	...	82·2	80·2	81·5	79·0	81·9	0·61					
„ 18	...	...	5·376	6·684	81·8	80·3	81·6	79·0	79·6	0·26					
„ 19	...	...	...	...	81·5	79·0	81·5	79·5	82·5	0·06					
„ 20	...	...	...	...	81·2	78·8	81·2	79·6	84·9		15′ 2″	25	17	32	19·24
„ 21	...	...	...	...	...	...	...	...	86·7						
„ 22	5·812	8·719	...	...	81·8	79·0	81·6	79·6	86·0						
„ 23	...	...	...	...	81·7	79·4	81·9	79·7	85·1	0·18					
„ 24	...	...	...	...	81·8	79·5	81·2	79·4	82·3	0·21					
„ 25	...	...	5·086	5·958	81·9	79·5	81·7	79·8	83·9	0·09					
„ 26	...	...	...	...	81·5	79·3	81·8	79·7	83·9						
„ 27	5·231	7·992	...	...	81·9	79·3	81·9	79·6	81·0	0·08	15′ 2″	18	23	43	19·69
„ 28	...	...	...	...	...	...	...	...	83·6	0·03					
„ 29	...	...	4·650	6·248	81·6	79·0	82·1	79·8	82·1	1·28					
„ 30	...	...	...	...	81·6	78·9	81·4	79·9	83·5						

TABLE VII.

Monthly Means of Soil-temperature, Water-level, etc., from February 1872 *to August* 1874.

Month.	Mean Maximum Temperature of Soil in Calcutta.		Rain-fall in Calcutta.	Average Temperature [open air].	Distance of water-level from surface in feet. [At Alipore.]
	3 feet from surface.	6 feet from surface.			
1872.					
February	70°7′Fahr.	74°0′Fahr.	2·82 inches.	72°9′Fahr.	13′8″
March...	75°2′	75°6′	0·21 „	83°1′	14′2″
April	82°1′	79°1′	1·83 „	85°9′	14′4″
May	84°3′	81°2′	1·99 „	87°0′	14′7″
June	85°3′	83°3′	9·45 „	85°4′	14′7″
July	82°2′	83°0′	5·55 „	83°3′	13′9″
August	82°0′	82°5′	11·52 „	83°1′	12′7″
September	82°0′	82°0′	8·42 „	83°2′	10′7″
October	88°8′	81°5′	8·93 „	81°6′	10′7″
November	75°7′	77°8′	0·02 „	76°6′	11′2″
December	72°3′	75°4′	0·09 „	70°3′	13′0″
1873.					
January	68°0′	72°4′	...	68°3′	13′7″
February	70°5′	72°5′	...	74°5′	14′4″
March...	75°8′	76°1′	1·18 „	80°3′	14′7″
April	81°8′	79°4′	1·84 „	84°4′	14′9″
May	83°4′	80°5′	3·78 „	87°0′	15′0″
June	84°8′	82°1′	4·30 „	88°2′	15′0″
July	83°3′	82°3′	14·76 „	83°5′	14′7″
August	82°0′	81°2′	10·23 „	83°5′	11′9″
September	82°3′	81°4′	5·82 „	84°5′	10′2″
October	80°1′	80°7′	2·40 „	82°1′	11′5″
November	76°2′	78°4′	0·14 „	76°0′	12′9″
December	72°6′	75°5′	0·82 „	70°2′	14′0″
1874.					
January	68°8′	72°8′	0·94 „	66°9′	14′7″
February	70°4′	73°0′	3·77 „	72°5′	14′10″
March...	74°3′	74°6′	0·94 „	78°6′	15′0″
April	80°7′	78°1′	1·20 „	85°4′	15′0″
May	83°4′	81°0′	1·16 „	87°4′	15′2″
June	82°4′	81°7′	6·89 „	83°9′	15′2″
July	81°5′	81°7′	8·89 „	84°2′	15′2″
August	81°0′	81°6′	10·19 „	83°1′	15′1″


INDIA
1877
Scale of English Miles
0 50 100 200 300
BAY of BENGAL
INDIAN OCEAN
NOTE.
The Numbers thus, 89 represent the percentage of the total Cholera registered at the Stations indicated, which has occurred among Troops and Prisoners in the Bengal Presidency during the Rainy Season, June to September.
BOMBAY
MADRAS
CALCUTTA
Laccadive Islands
Maldeeve

To face p. 205.

CHOLERA IN RELATION TO CERTAIN PHYSICAL PHENOMENA:

A CONTRIBUTION TOWARDS THE SPECIAL ENQUIRY SANCTIONED BY THE RIGHT HON. THE SECRETARIES OF STATE FOR WAR AND FOR INDIA.*

BY

T. R. LEWIS, M.B., AND D. D. CUNNINGHAM, M.B.

INTRODUCTION.

THE RELATION OF SOIL TO DISEASE.

THE question of the influence of conditions of the soil on the prevalence of cholera has been for some years the subject of special enquiry in this country, and the primary object of the present report is to show what the results of this investigation have been up to the present time. The varying conditions of the soil are, however, so intimately associated with meteorological conditions in the ordinary sense of the term—the two sets of phenomena acting and re-acting on one another mutually—that, when the subject was entered upon, it was found impossible to leave the latter out of consideration, and the enquiry has therefore been made a more or less general one into the physical conditions of localities, associated with the seasonal prevalence of cholera in them.

That the prevalence of cholera in any locality is more or less affected by the coincident meteorological and other physical conditions is generally admitted by the adherents of all theories regarding the essential cause of the disease, but comparatively little has been done to investigate the actual relation which the phenomena bear to one another. It is true that the special committee for scientific enquiries appointed by the Board of Health in 1854 included the subject in its meteorological aspect among the matters for investigation, and that more recently the questions of the relation of wind, of soil, and of rain-fall to cholera have been discussed by various authorities, such as Drs. von Pettenkofer, Macpherson, Bryden and Macnamara, but in spite of this there is still abundant room for close enquiry. This is in part due to the fact that most of those who have considered the matter at all have, to

* Appeared as an Appendix to the *Thirteenth Annual Report of the Sanitary Commissioner with the Government of India*, 1878.

some extent, only done so in so far as special phenomena have appeared to lend support to special views regarding the cause of the disease, while neglecting to consider others, which either appeared to have no direct bearing on such views, or were even difficult to reconcile with them.

In the following pages an attempt has been made to bring together the scattered data which appear to be of importance in studying the relation which the prevalence of this disease in the province of Bengal may bear to certain conditions of soil and of air, and to incorporate with them such of the new observations as appear to be sufficiently advanced to warrant some conclusions being derived from them.

Under the orders of the Government, daily observations have been recorded at numerous stations all over India, in the presidencies of Bombay and Madras, as well as in Bengal, regarding the fluctuations which the subsoil water undergoes. In the military cantonments these were conducted during 1870 and the greater part of 1871, but in several of the civil stations the registration has been continued until the present time. In 1875 the observations were limited to four or five stations in each province, as, with the information already acquired, it was considered that these would suffice for the future.

The registration of the water-level was undertaken not only for the purpose of endeavouring to ascertain whether any relation existed between the degree of the prevalence of cholera and the hygrometric state of the soil, but also in the hope that continuous and systematic observations of this character might aid in enabling the profession to come to some definite conclusion with regard to the cause of the various fevers which so frequently recur in certain districts, and cause such terrible devastation.

As is well known, the credit of drawing attention to these matters in modern times belongs to the distinguished Professor of Hygiene at the Munich University, Dr. Max von Pettenkofer; and their investigation in India was undertaken at the suggestion of the Army Sanitary Commission, in consultation with the late Dr. Parkes and the other Professors of the Army Medical School.* As some miscon-

* The previous reports which have appeared in connection with the Special Cholera Enquiry sanctioned by the Secretaries of State for War and for India, and which have been published in former Annual Reports of the Sanitary Commissioner with the Government of India, are the following :—

1. Microscopic Appearances of Choleraic Discharges—The Fungus Theory, etc. App. A, *Sixth Annual Report*, pp. 124—178, Calcutta, 1870.

2. Cholera in Madras—Topographical and Microscopic Observations. App. B, *Seventh Annual Report*, pp. 139—236, 1871.

3. Cholera : Microscopical and Physiological Observations—Series I.—*Eighth Annual Report*, App. C, pp. 143—203, 1872. (Republished in *Indian Annals of Medical Science*, No. 30, vol. XV, 1873.)

4. Microscopic Examinations of Air. *Ninth Annual Report*, App. A, 1—54, 1873.

5. Cholera : Microscopical and Physiological Observations—Series II.—*Tenth Annual Report*, App. A, pp. 173—210, 1874. (Republished in *Indian Annals of Medical Science*, No. 35, vol. XVIII, 1876.)

6. The Soil in its Relation to Disease. *Eleventh Annual Report*, App. B, pp. 117—143, 1875. (Republished in *Indian Annals of Medical Science*, vol. XVIII, 1876.)

ception appears not uncommonly to exist even yet as to the object which Dr. von Pettenkofer had in view in advocating the system of water-level registration and the method in which the data thus acquired should be interpreted, perhaps it may be advantageous to give a general outline of what we ourselves conceive to be his views on the subject. In his now celebrated lectures on "The Air in relation to Clothing, Dwelling and Soil,"* a lucid description is given of the relation which the air in the soil bears to the air above it: how the air in the pores of the soil is kept constantly moving by the force of the wind passing over the surface of the ground, and by the laws regulating the intermingling of gases—change of temperature, diffusion, and so forth.

As an illustration of the differences which soils present, he points out how experience has shown that in some graveyards the decomposition of bodies is complete in from six to seven years, whereas in others twenty-five or thirty years are required before this is brought about; so that it has become a matter of practical import to ascertain the quality of the ground in this respect, when selecting sites for cemeteries, as the interval which should elapse before a burying-ground may be used again hinges upon the fact as to whether decomposition takes place rapidly or not; hence it may happen that two cities with an equal population may require cemeteries of very different extent. He mentions that several influences combine to bring this about, but the principal one is the amount of, and the facility for, the interchange of the air in the soil—gravelly and sandy soils acting much more quickly than those of marl and clay.

Elsewhere this *savant* points out that changes, such as these, are materially expedited by variations in the degree of the soil-moisture: wood is preserved as well in water as in dry air, but it rots when subject to alternations of dryness and moisture.

It is not on the particular degree of soil-moisture that Dr. von Pettenkofer lays stress, but on the variations in it, and he suggests the fluctuation of the ground-water as a convenient index of this, especially in Europe. With regard to India, however, he throws out the suggestion that experience may show that the rain-fall may serve as a clearer index than the water-level, as the former is not so irregularly distributed throughout the year as in Europe.† Mr. H. F. Blanford, in a work recently published, also points out the marked difference which exists between European and Indian meteorological manifestations, and remarks that "order and regularity are as prominent characteristics of our atmospherical phenomena as are apparent caprice and uncertainty those of their European counterparts."‡

Granted that certain organic or inorganic processes take place in the soil and give rise to various diseased conditions, it would still be necessary to show how

* *Beziehungen der Luft zu Kleidung Wohnung und Boden*, 1872.

† *Verbreitungsart der Cholera in Indien*, 1871. S. 95.

‡ *The Indian Meteorologist's Vade Mecum*, 1877, p. 144.

these changes could affect such portions of the community as spend the greater part of their time in-doors. To this Dr. von Pettenkofer replies by instancing cases of poisoning from gas which have occurred in houses unconnected directly with gas-pipes, the warmer air of the house acting like a heated chimney, having drawn up the soil-air through the ground on which the houses stood and thus conveyed the gas which had escaped from pipes placed in the earth outside the dwelling. Instances are referred to of this having occurred, although the gas had to travel some 20 feet under the street and through the foundation and flooring of the house.

Quite recently these statements have received marked corroboration from Dr. Cobelli of Roveredo,* who gives details regarding a case of the kind where a mother and her two daughters, a dog and a bullfinch in its cage, were one morning found poisoned in a bedroom. The two daughters were already dead and the bird also; the mother died shortly afterwards; the dog alone recovered. The State ordered an enquiry to be held, as it was scarcely conceivable that the deaths could be attributed to an escape of gas, as no pipes were connected with the house. That gas could get into the room, however, was shown by analysis of the air which it contained, and after minute investigation it turned out that gas was escaping through an imperfectly fitting plug of one of the main pipes which had been sunk about a yard below the surface (in earth of an alluvial nature), and 15 feet 7 inches removed from the room in which the poor people had slept. The gas had been aspired into the room instead of escaping into the street, for the air of the room at night had been warmer than the air outside.

The importance of bearing observations of this kind in mind in connection with attempts at tracing to their source foul emanations from covered sewers and other unwholesome subsoil recesses and tracts, is too obvious to require special note.

It is in this light that, as we understand it, Dr. von Pettenkofer suggests that the relation of soil-influences should be studied, and urges that it is absolutely necessary that each locality should be studied for itself at different times, seeing that constant variations take place not only in the generating power of the soil, but also in its porosity, or, in other words, in its capacity for permitting any noxious elements which it might contain to mingle with the upper air. A layer of asphalt beneath the flooring of that gas-infected house would doubtless have prevented the occurrence of poisoning, as would, possibly equally well, a layer of *wet* clay.

With this brief summary of our conception of the learned Professor's views, we pass on to draw attention to the epitome of the Water-Level Registers [Tables I to VII at the end of this paper] which have been kept in Bengal during the last seven years. Some of the returns we have been obliged to leave out of the tables, owing to obvious and irremediable inaccuracies, due, probably in great part, to misconception on the part of the observers as to the precise nature of the information required.

* *Zeitschrift für Biologie*, Band XII, S. 420.

Some other returns which were also manifestly incorrect we have been able in some degree to rectify, especially such of them as presented inverse reading of the fluctuations of the water-level. These have been marked with an asterisk in the tables. It will be observed, also, that at some of the stations observations have been made only during very short periods. These have, however, been put on record, as they may, perchance, be of use to future observers in studying localised outbreaks of disease that may occur at those particular stations.

In the water-level returns for Calcutta, the monthly mean of the daily returns has been calculated for all the years; but with regard to the others, the observation recorded in the middle of each month has been taken as offering sufficiently precise information.

It was our intention to have analysed the records obtained from Madras and Bombay on the present occasion also, but we found that the task was more than could be accomplished satisfactorily at present. On a future occasion we hope to deal with these also, and to do so, if practicable, not only in connection with the question of cholera, but also with relation to the prevalence of malarial fevers and dysentery.

I.—CHOLERA IN CALCUTTA.

CHAPTER I.

THE SEASONAL FLUCTUATIONS IN THE PREVALENCE OF CHOLERA IN AN *ENDEMIC* AREA—CALCUTTA.

Of all regions where the nature of the influence of seasonal conditions on the prevalence of cholera can be enquired into, the endemic area of the disease, and more especially the endemic area as represented by the lower portion of the Gangetic delta, is perhaps the best adapted to the end in view. In it the constant presence of the disease and the regularity with which the phenomena of fluctuations in its prevalence occur, furnish data which are more readily comparable with those of a physical nature than can be obtained in regions where cholera only occurs occasionally and in epidemic outbursts. The data regarding a typical locality in this area—Calcutta—have therefore been gone into at considerable length and in greater detail than has been attempted in reference to other places; but regarding almost all the localities considered in the report, sufficient data are supplied to allow of their comparison with Calcutta in most important respects.

Our data regarding the varying prevalence of cholera in Calcutta at different times of year are mainly derived from three sources—1*st*, the table published by Dr. John

Macpherson in his work on "Cholera in its Home;"* 2*nd*, that contained in the Report of the Health Officer for Calcutta for the year 1876;† and 3*rdly*, Dr. Bryden's statistical tables regarding the European troops in Fort William and the inmates of the Alipore Jail. Tables showing the data regarding the occurrence of the disease in the Native troops in Fort William and in Alipore are also included in the following pages, but they are of little value compared with the others, including, as they do, the results of only a very limited number of years.

The figures furnished by Dr. Macpherson include those contained in the monthly returns of deaths from cholera in Calcutta for a period of 26 years. They are shown in he following table:

TABLE VIII.

Total deaths returned as due to Cholera in Calcutta during each month for a period of twenty-six years.

Months.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Total.
Deaths ...	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323	8,159	104,295

Dr. Payne's table includes the deaths returned during each month from 1865 to 1876, and is as follows:—

TABLE IX.

Monthly Cholera deaths in Calcutta from 1865 *to* 1876.

Years.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
1865	136	396	508	756	400	131	162	392	496	432	817	452
1866	509	826	1,193	736	616	885	552	491	371	236	203	208
1867	67	142	292	343	315	137	108	56	150	277	243	140
1868	252	328	694	591	360	174	97	395	188	350	405	352
1869	264	428	760	746	698	331	78	53	41	57	78	58
1870	171	259	257	382	165	118	50	40	30	37	22	32
1871	53	96	55	85	29	23	25	41	70	86	128	109
1872	80	81	64	70	66	55	71	79	61	86	181	248
1873	133	189	221	163	153	99	59	31	26	24	28	29
1874	69	182	193	250	217	86	42	39	24	29	67	131
1875	130	73	268	268	119	66	32	35	55	150	358	172
1876	91	226	343	268	168	126	42	32	31	41	259	244
Total	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789	2,175

As these tables furnish by far the most important data which we possess in reference to the seasonal prevalence of cholera in Calcutta, it may be well to consider their results

* London: John Churchill and Sons, New Burlington Street, 1866.

† Report of the Health Officer for Calcutta, by A. Payne, M.D., Calcutta, 1877.

alone first, reserving those regarding the more limited communities to be noticed afterwards.

That their results in general agree very closely is evident even on a casual inspection. The first table gives a total of 104,295 for the 26 years' mortality, or an average of 8691·2 per month when the entire period is sub-divided into 12 monthly periods.

The month in which the actual numbers most nearly approach this average is November, the 26 years' deaths of which are 8,323.

The second table for 12 years gives a total mortality of 31,538, or a monthly average of 2628·1. Here again November, with a total mortality of 2,789, is the nearest to the average. We are thus justified in regarding November as a month of average cholera-prevalence—as a month presenting the conditions producing the disease in a state of medium intensity—and consequently in employing it as a starting-point for comparison, and the conditions then existent as bases for the study of those present at other times.

The order, proceeding from minimum to maximum, which the individual months hold in regard to prevalence in the two tables, is shown in the following table, which also includes a third column, showing the order in prevalence since the beginning of 1871 :—

TABLE X.

Months arranged in order of Cholera-prevalence from minimum to maximum.

Order.	Dr. Macpherson's table.	Dr. Payne's table.	Dr. Payne's table from 1871.
1	August.	July.	August.
2	September.	September.	September.
3	July.	August.	July.
4	October.	October.	October.
5	June.	January.	June.
6	January.	December.	January.
7	December.	June.	February.
8	November.	November.	May.
9	February.	February.	December.
10	May.	May.	November.
11	March.	April.	April.
12	April.	March.	March.

Comparing the first two columns, we find the differences to be as follows: July and August occupy reversed positions, August coming first and July third in the first column, while July comes first and August third in the second one. In both columns October occupies the fourth place, but June, which in the first column precedes, in the second follows, January and December. In both columns the rest of the order is identical, save that in one April, in the other March, comes last.

Next, comparing the first and third columns, we find an entire agreement for the first six months; but after this, December and November change places with February and May, whilst March and April again occur in reversed order. The principal use of the second comparison is to show how, in examining the results of very short periods, whilst we find a general agreement with those of longer ones, minor differences are introduced by the exceptional occurrences of particular years.

Returning now to the consideration of the tables as a whole, it will be found that the agreement between their results may be considerably augmented by removing the figures regarding one great cholera season—that of 1865-66—from the second table. If we do this, starting with September 1865, in which the great rise in prevalence began, and removing the figures of each of the subsequent months up to the following September, we get the following series of figures as the monthly totals for the remaining 11 years:—

TABLE XI.

Total Cholera Deaths from 1865 *to* 1876, *exclusive of the period between September* 1865 *and September* 1866.

Months.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Deaths	1,446	2,400	3,655	3,922	2,690	1,346	766	1,193	1,047	1,373	1,927	1,723

The tables now agree, save that June and July change places with October and August. April now appears in both tables as the month of maximum prevalence, and the relation which the figures for November and December bear to one another comes to be closely similar in both cases.

Let us now see what the average annual course of cholera as exhibited in these figures really is. Taking November as most nearly representing the average prevalence of the disease, and therefore as a good starting-point, we find successive diminutions in prevalence during December and January, a rapid rise in February, continuing to the maximum in March and April, a marked diminution in May, continued through June, to a minimum in July, August and September, and finally a rise in October to reach the average in November. Stating the facts of prevalence in most general terms, it may be said that there are four months in which the prevalence of cholera greatly exceeds the average, three months in which it falls far short of it, and five months in which it ranges round it, the prevalence in November approaching it more nearly than that of any other month.

Such are the results of the more important masses of data at our disposal, and we may next examine those relative to various limited communities in order to see how far they agree with the others.

The next two tables contain the deaths from cholera which occurred among the European troops in Fort William from 1826 to 1857, and the admissions from 1826 to 1849 and 1858 to 1876. The figures are those of Dr. Bryden's statistical tables regarding cholera. Deaths have been stated separately from admissions, because they are less liable to suspicion in respect of errors of diagnosis,* and because the previous statistics which we have been considering have referred to deaths alone. The returns of admissions per month in Dr. Bryden's tables cease with the year 1849, after which only deaths are given until 1858, from which date monthly admissions and total annual deaths are recorded, and it is on this account that our two tables do not embrace the same period of years.

* In reference to this point, it is to be noted that some of the returns regarding Fort William are very open to suspicion ; for example, we find that in 1838, 126 admissions and only 8 deaths from cholera are recorded, giving a rate of mortality very unlike that which is encountered in true cholera at the present time. The numbers of admissions and of deaths, with the percentages of the latter to average strength from 1826 to 1876, are as follows :—

TABLE XII.

Annual Returns of Cholera among European Troops in Fort William.

Year.	Cholera.			Year.	Cholera.		
	Admissions.	Deaths.	Percentage of deaths to strength.		Admissions.	Deaths.	Percentage of deaths to strength.
1826	84	46	7·6	1852*	...	20	...
1827	40	18	1·9	1853*	...	13	...
1828	26	13	1·4	1854*	...	6	...
1829	46	14	1·5	1855*	...	21	...
1830	57	11	1·0	1856*	...	41	...
1831	17	4	0·4	1857*	...	73†	...
1832	19	2	0·2	1858	92	55	7·1
1833	20	5	0·7	1859	14	9	0·6
1834	10	3	0·4	1860	59	40	3·3
1835	15	0	0·0	1861	18	9	0·8
1836	7	0	0·0	1862	16	13	1·4
1837	7	1	0·1	1863	5	4	0·5
1838	126	8	0·8	1864	7	2	0·2
1839	9	2	0·2	1865	0	1	0·1
1840	37	17	2·3	1866	4	2	0·2
1841	69	23	3·3	1867	3	2	0·2
1842	118	59	6·1	1868	5	5	0·5
1843	24	15	1·4	1869	0	0	0·0
1844	15	7	1·3	1870	4	2	0·2
1845	29	14	3·0	1871	0	0	0·0
1846	31	21	4·4	1872	2	1	0·1
1847	5	2	0·3	1873	3	1	0·1
1848	12	9	1·1	1874	1	1	0·1
1849	5	4	0·4	1875	0	0	0·0
1850*	...	6	...	1876	5	5	0·4
1851*	...	20	...				

* 1850 to 1857 records of admissions are incomplete, and the strength not known.

† Fort William and Calcutta hospitals (soldiers, sailors, etc. ?).

TABLE XIII.

Cholera deaths among European Troops in Fort William, 1826 *to* 1849 *and* 1850 *to* 1857.
[*The figures of latter period refer to deaths of European Troops in "Calcutta."*]

Months.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Deaths ... 1826—49	9	19	37	77	75	16	8	6	9	12	22	7
,, ... 1850—57	2	14	19	28	11	32	3	10	24	10	27	19
TOTAL	11	33	56	105	86	48(*a*)	11	16	33(*b*)	22	49	26

(*a*)—Thirty-one occurred in June 1857. | (*b*)—Twenty-three occurred in September 1856.

TABLE XIV.

Cholera admissions among European Troops in Fort William, 1826 *to* 1876.
[*Deaths alone registered during* 1850-55 *and* 1857.]

Months.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Admissions	51	72	169	274	212(*a*)	107	59	65	84	64	100	62

(*a*)—Forty-nine of these admissions occurred in 1826.

These tables show results which, in reference to the general phenomena of the fluctuations in the prevalence of cholera, substantially agree with those regarding the population at large. This is specially the case with that referring to deaths, which we have already seen cause to regard as the one more accurately representing the facts. The principal points of difference between the results lie in the greater relative fall in prevalence in December and January among the troops, and in the fact that among them the months of maximum prevalence are April and May, in place of March and April. The general phenomena of the rise of prevalence at the close of the rainy season, followed by a fall during December and January, and of a second great rise in the succeeding months, followed by a great fall during the rains, are exactly those which we met with in the former tables.

The following tables show the number of admissions from cholera among the Native troops in Fort William and in Alipore cantonment from 1864 to 1876:—

TABLE XV.

Cholera Admissions among Native Troops in Fort William, 1863-64 *and* 1867 *to* 1876.

Months.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Admissions	3	6	4	11	19	8	0	0	3	1	5	4

TABLE XVI.

Cholera Admissions among Native Troops in Calcutta [Fort William and Alipore], 1852 to 1876.

Months.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Admissions	14	37	94	97	85	41	34	19	21	15	27	26

The period included is of such short duration that it is remarkable to find how far these tables corroborate the results of the previous ones.

Our last sources of data regarding seasonal prevalence lie in the great jail at Alipore. Only 39 cases are recorded as having occurred at the Presidency jail (1872 to 1876). The following table shows the figures regarding cholera admissions in the Alipore Jail from 1854 to 1876. Like the previous tables, its materials are derived from Dr. Bryden's statistics of cholera :—

TABLE XVII.

Cholera Admissions in Alipore Jail, 1854 to 1876.

Months.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Admissions	29	101	284	153	60	114*	133†	35	41	69	77	32

* Forty-one of these admissions occurred in 1866.

† Nineteen of these admissions occurred in 1858 and thirty-four in 1859.

The results in this last table differ from those in the former ones in showing a comparatively high prevalence in June and July. This discrepancy is, however, greatly reduced in importance, when we find that 41 of the total admissions in June occurred in one year, and 53 of those in July in two successive years.

The evidence afforded by this series of minor tables regarding limited communities is confirmatory of the general correctness of the indications afforded by the statistics of the first two, and it is of importance to observe how much data derived from limited communities may furnish trustworthy indices regarding the seasonal prevalence of disease. The great requirement is, that they should embrace a sufficiently prolonged period to do away with the fallacies introduced by exceptional outbreaks; where this condition is fulfilled, such data may be resorted to with tolerable confidence. It is evident that such figures, when thus employed, are in great measure free from the sources of fallacy inherent in them when employed as an index of the general prevalence of cholera among the population at large in one year as compared with another.

CHAPTER II.

A COMPARISON OF THE SEASONAL FLUCTUATIONS IN INDIVIDUAL PHYSICAL CONDITIONS WITH THOSE IN PREVALENCE OF CHOLERA IN CALCUTTA.

HAVING acquired this information regarding the seasonal fluctuations in the prevalence of cholera, we have now to enquire into the meteorological and other physical conditions coincident with them, in order, if possible, to determine whether any connection be traceable between the two series of phenomena; whether, in fact, there be any series of meteorological and physical constants characterising the various seasons of prevalence when compared with one another.

The conditions which have been selected for consideration are. (1) atmospheric pressure, (2) air-temperature, (3) atmospheric humidity, (4) rain-fall, (5) water-level, (6) soil-temperature, and (7) amount of carbonic acid in the soil-air—mainly regarded as an index of soil-ventilation.

The sources from which our data regarding these conditions are derived are the following:—(1) the Report on the Meteorology of India in 1875, by Mr. H. F. Blanford, Meteorological Reporter to the Government of India; (2) the Report of the Meteorological Reporter to the Government of Bengal for 1874; (3) the Abstracts of the Meteorological Observations taken at the Surveyor General's Office from the year 1856; (4) the register of water-level kept at the Alipore Jail by Dr. S. Lynch since 1870; (5) our own observations regarding the temperature and carbonic acid of the soil-air.

(a) Atmospheric Pressure.

The accompanying diagram and table show the phenomena of atmospheric pressure compared with cholera prevalence. In the diagram the line of atmospheric pressure is drawn to the second decimal place of the 9 years' averages given in Mr. Blanford's report and reproduced in the table. The cholera line was originally constructed on a scale allowing one graduation to every thousand, and the figures employed are those of the total obtained on adding Drs. Macpherson's and Payne's statistics together. The figures in the table explain themselves.

TABLE XVIII.

Average Monthly Atmospheric Pressure (9 *years*) *compared with Cholera-prevalence.*

		Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Average pressure ...		29·980	30·030	30·011	29·948	29·856	29·757	29·665	29·550	29·545	29·608	29·689	29·831	29·980	29·787
Cholera.	(Macpherson) ..	8,323	8,159	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323	104,295
	(Payne)	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1.684	1,543	1,805	2,789	31,538
	TOTAL	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112	135,833

It will be observed that in both table and diagram the months are arranged starting from November, in place of from the commencement of the calendar year. The same arrangement has been followed in the subsequent tables and diagrams in connection with Calcutta. The arrangement was adopted because November, as the month of average prevalence, forms a good starting point for comparison; but other advantages also attend it, one of which is that, so far as the phenomena of rainfall are concerned, October makes a more natural termination to the year than December.

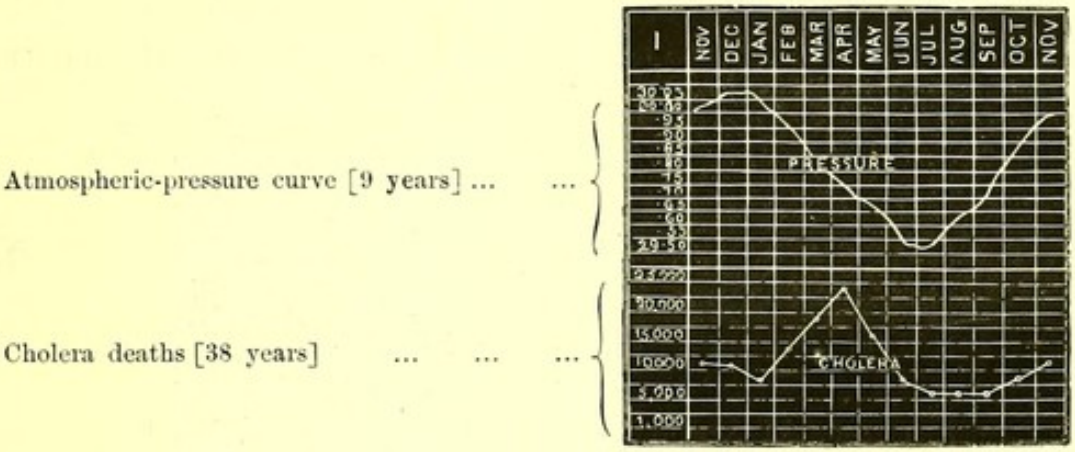


DIAGRAM 1.—Atmospheric Pressure and Cholera-prevalence in Calcutta.

The result of the comparison shows that the season of minimum prevalence is characterised by low atmospheric pressure. Farther than this, however, the coincidence ceases. There is no indication of the existence of any definite relation between degree of atmospheric pressure and prevalence of cholera. December and January, the months of maximum pressure, show less prevalence than November on the one hand, and much less than February, March, April, and May on the other. So again June shows lower atmospheric pressure, but much higher prevalence than August and September. Atmospheric pressure, considered in the light of these data, cannot be regarded as exerting any direct influence on the prevalence of cholera. The coincidence of low atmospheric pressure with minimum prevalence must be regarded as such only, or if any influence be exerted by the pressure, it must act through some intermediate agency.

(b) Atmospheric Temperature.

A mere glance at the table and diagram below renders it evident that temperature, if it exert any influence on the variations in prevalence of cholera in Calcutta, does so only in a very subordinate way. We find periods of maximum, minimum and medium prevalence occurring with an almost unaltered temperature. For example, the average temperatures of April and July only differ by 1°·2, whilst the former month is one of maximum, the latter one of minimum prevalence. Again, the temperatures of March

TABLE XIX.

Average monthly Temperature (23 years) compared with Cholera-prevalence.

		Nov.	Dec.	Jan.	Feb.	Mar.	Apr.l.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Average Temperature		74·9	68·1	67·7	73·0	80·5	84·7	86·2	84·9	83·5	83·1	83·3	81·5	74·9	79°·3
Cholera.	(Macpherson) ...	8,323	8,159	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323	104,29[illegible]
	(Payne)	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789	31,53[illegible]
	TOTAL ...	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112	135,83[illegible]

and October differ only by 1°·0, but March is a month of maximum, October of medium, prevalence :—

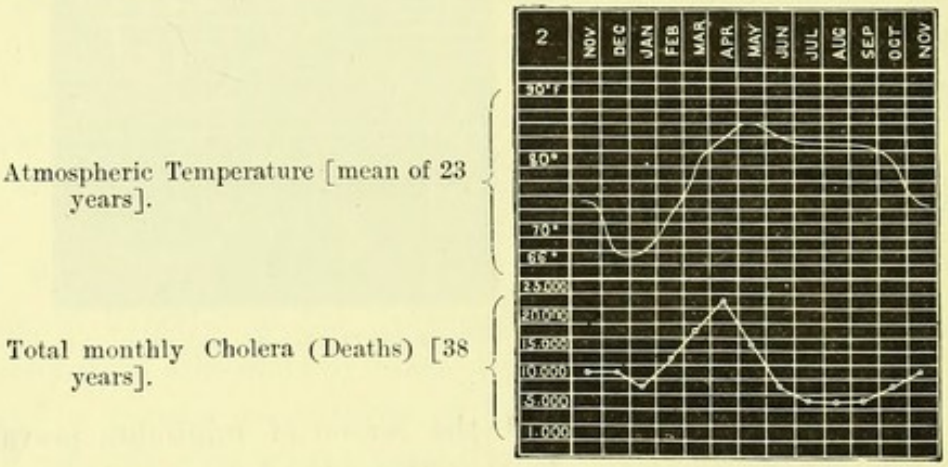


DIAGRAM 2.—Atmospheric Temperature and Cholera-prevalence in Calcutta.

Whilst this is the case, there is at the same time some evidence which seems to be in favour of the temperature exerting a subordinate influence on the prevalence. Taking the months from November to April, we get the following results:

TABLE XX.

Temperature and Cholera from November to April.

	Nov.	Dec.	Jan.	Feb.	March.	April.
Temperature	74·9	68·1	67·7	73·0	80·5	84·7
Cholera	11,112	10,334	9,105	12,572	19,558	24,040

Starting from November, we have two months of diminishing temperature and prevalence followed by three months of increasing temperature and prevalence. This alone would hardly afford ground for any positive conclusion; but we shall find hereafter, in considering the data regarding other conditions, that some disturbing influence manifests itself during December and January, breaking in on the coincidence between the prevalence of cholera and those conditions which otherwise correspond in their

fluctuations most accurately with those of the disease, and there is hardly anything else to which we can ascribe this save the temperature. Taking this into consideration together with the well-established fact of the general tendency to subsidence or even disappearance of the disease during the winter months of periods of its epidemic manifestation in Europe, there appear to be grounds for ascribing some influence to the atmospheric temperature on the prevalence of cholera in Calcutta. The precise method in which it acts remains, however, undetermined. That it acts directly is extremely improbable, but there are many indirect means by which it may produce an effect. Whatever the latter may be, they must, at all events, be entirely independent of peculiar habits of life of one section of the community as compared with another, for we find as marked a decrease in prevalence among the European troops as among the Native community.

(c) Atmospheric Humidity.

TABLE XXI.

Average monthly Atmospheric Humidity (8 years) compared with Cholera-prevalence.

		Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
	Humidity ...	71	68	68	68	67	73	75	83	87	88	87	80	71	76
Cholera.	(Macpherson)...	8,323	8,159	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323	104,295
	(Payne) ...	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789	31,538
	Total ...	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112	135,833

The diagram differs from the previous ones in its method of construction, the line showing the Relative Humidity representing the reverse and not the direct relation; in other words, the lower the degree of humidity, the higher the scale on the diagram. This plan has been adopted because there is a certain amount of coincidence between diminished humidity and increased cholera-prevalence in Calcutta, and the coincidence being of the reverse nature, the amount of it is rendered more clear by arranging the lines accordingly.

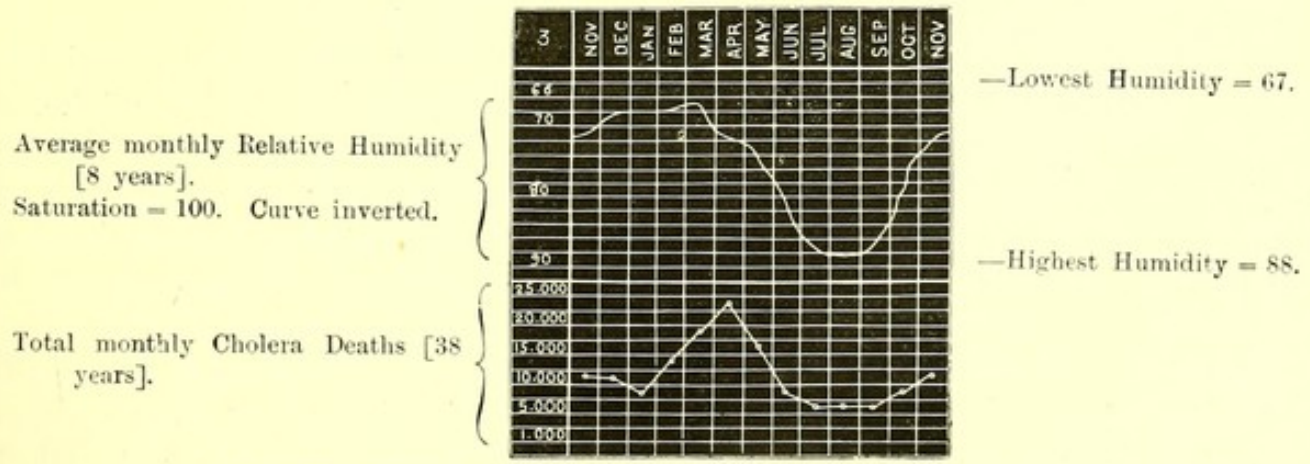


DIAGRAM 3.—Atmospheric Humidity and Cholera-prevalence in Calcutta.

Starting as usual from November, we find a considerable decrease of humidity in December, continuing until February, and followed by a slight fall to the minimum in March. A considerable increase occurs in April, followed by a smaller one in May next follows a rapid increase through June and July to the maximum in August. This is followed by a slight fall in September, succeeded by a considerable fall in October, and an even greater one in November. The above data refer to the facts of 8 years, but very much the same results are shown in the following table of monthly averages from November 1864 to October 1876, which was specially compiled from the meteorological abstracts of the observations taken at the Surveyor General's Office for comparison with the figures of cholera-prevalence of the same period.

TABLE XXII.

Average monthly Humidity (*November* 1864 *to October* 1876) *and average monthly Prevalence* (*January* 1865 *to October* 1876).

Month.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Humidity ...	70	68	69	66	65	68	72	80	85	86	85	77	70
Average cholera	230	175	162	268	404	388	275	185	109	140	128	150	230

In this table the humidity of November is slightly lower than in the previous table. That of December is the same as in it, but January shows a slight increase, and February a decrease as compared with December. March again gives the minimum humidity, but the rise between March and April is less than that between April and May. August again gives the maximum, and July and September are equal as before. We again encounter a rapid fall in October and November, but the fall between September and October is greater in place of less than that between October and November. Taken generally, however, the results of the two tables agree closely, the periods of maximum and minimum being identical in both.

On comparing these data with the figures of cholera, some very striking coincidences present themselves. We find the periods of maximum prevalence and of minimum humidity, and of minimum prevalence and maximum humidity, coinciding very closely. Taking Dr. Payne's figures alone, we have maximum prevalence and minimum humidity in March, and taking Dr. Macpherson's figures, or the total of both sets, we find minimum prevalence and maximum humidity in August. Not to lay much weight on such details, there can be no doubt of the general coincidence of the phenomena of seasonal prevalence in Calcutta with those of the seasonal fluctuations in atmospheric humidity. The maximum and minimum periods hold a reverse relation; there is a rapid rise in cholera coincident with an equally rapid fall in humidity during October and November, and a similar phenomenon of coincident fall

in prevalence and rise in humidity occurs in May and June. The greatest want of coincidence is presented by the phenomena of December and January and of April. In December and January, as compared with November, there is diminished prevalence coincident with diminished humidity, and in April compared with March, there is increased humidity coincident with a prevalence which our data lead us to regard as increased in place of diminished.

The question of the influence of temperature may here be recurred to in reference to the exceptional relations occupied by the humidity and prevalence of December and January. Assuming that elevation of temperature and depression of humidity favour the prevalence of cholera in Calcutta, and that the opposite conditions produce a reverse effect, let us endeavour to estimate the combined effect of the conditions of temperature and humidity present in each individual month. For convenience of calculation, degrees of temperature and of humidity may be regarded as of equal value in reference to prevalence. We know that November is a month in which prevalence is of nearly average intensity, and the conditions of the month which favour prevalence must therefore occupy a similar position in respect to those of other months. The humidity of November is 71, its temperature is 74°·9. Passing to December, we have a humidity of 68 and a temperature of 68°·1; that is, we have increased prevalence favoured by 3 degrees of humidity, and diminished prevalence favoured by 6·8 degrees of temperature. According to this there is an excess of 3°·8 in favour of diminished prevalence, and the conditions of December in respect of temperature and humidity in relation to prevalence are as—3°·8, compared with those of November as zero.

Proceeding in the same way with the remaining months, we obtain the following series of figures:—

TABLE XXIII.

Relations of the various months in respect of combined influence of Humidity and Temperature.

Months.		Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Combined conditions.	For 8 years	0·0	—3·8	—4·2	+2·1	+9·6	+7·8	+7·3	—2·0	—7·4	—8·4	—7·6	—3·4	0·0
	For 12 years	0·0	—4·5	—6·1	+1·7	+10·3	+11·5	+8·7	—0·2	—6·8	—8·1	—7·0	—0·5	0·0

The relation borne by the combined conditions of temperature and humidity to cholera prevalence is shown in Diagram 4 of the phenomena for the twelve-year period.

It certainly is curious how closely the line representing the aggregate of conditions here assumed to influence the prevalence of cholera corresponds with that representing the actual prevalence.

Comparisons of the phenomena of individual years fail to show such close correspondence between conditions of atmospheric humidity and prevalence as is indicated by the present data. It must, however, be borne in mind, that in order to institute accurate comparisons for brief periods, such as individual months, it would be necessary to know the actual distribution of the cholera prevalence throughout their course, and

A combined Relative Humidity and Temperature curve [12 years].

Total monthly Cholera Deaths [12 years].

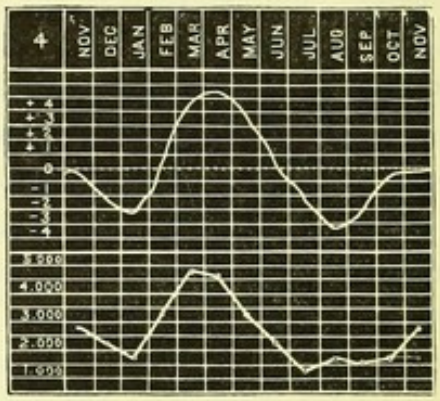


DIAGRAM 4.—Relations of Cholera-prevalence for 12 years to contemporaneous Humidity and Temperature.

to compare the data with those of the actual humidity coincident with the prevalence at different times, the mere monthly averages of the two phenomena being in this case evidently capable of giving rise to very incorrect conclusions. Moreover, the degree of atmospheric humidity cannot be supposed to act directly in producing prevalence; it can only act by increasing predisposition or by favouring the development, diffusion, or preservation of the agent producing the disease, so that any influence which it possesses may be neutralised by the action of other conditions.

(d) Rainfall.

TABLE XXIV.

Average monthly Rainfall (47 years) compared with Cholera-prevalence.

Months.		Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Year.
Rainfall		0·66	0·24	0·44	0·83	1·28	2·49	5·46	12·13	12·64	13·71	10·17	5·61	0·66	65·6
Cholera.	(Macpherson)...	8,323	8,159	7,150	9,346	14,710	19,382	14,335	6,325	3,979	3,440	3,935	6,211	8,323	104,295
	(Payne)... ...	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789	31,518
	TOTAL ...	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112	135,833

In this diagram, as in Diagram 3, the line representing the rainfall has been inverted, in order to show the somewhat reverse relation occupied by the rainfall and cholera-prevalence. Beginning with the question of average rainfall, we find, first, a period of months in which the rainfall does not amount to one inch, then three months

with a fall ranging from 1·28 in March to 5·46 in May. Next follows a second period of four months—that of the rainy season—with averages ranging from 10 to nearly

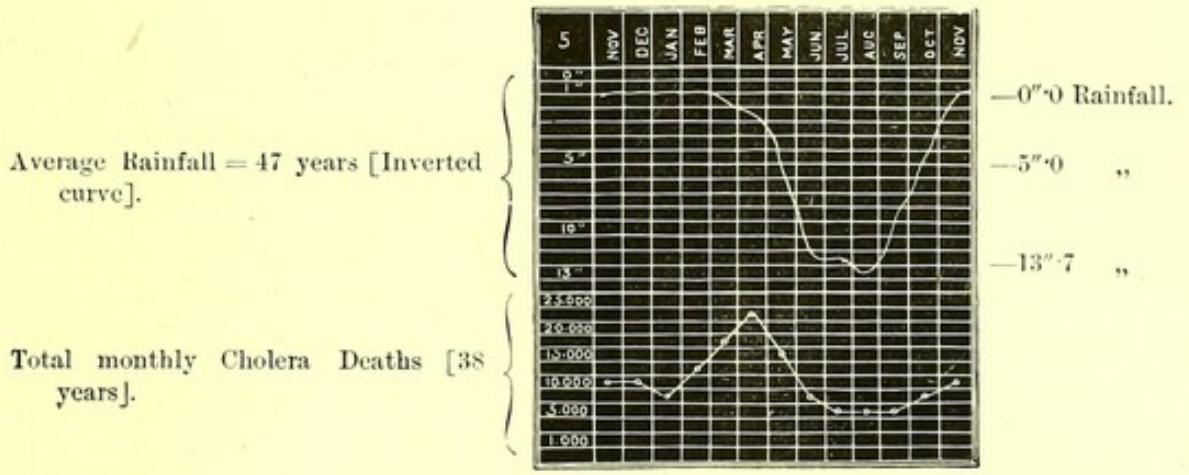


DIAGRAM 5.—Rainfall and Cholera-prevalence in Calcutta. (The Engraver has not kept the curve rigidly to the scale in some parts.)

14 inches, and finally we have October with an average of 5·61 inches, which is almost identical with that of May. Stated generally, there are four months of maximum, four months of minimum, and four months of intermediate rainfall; but whilst the months of maximum and minimum form continuous groups, the intermediate months are divided into two unequal sections by the other periods, three of them intervening between the minimum and maximum, and the fourth between the maximum and minimum periods.

On comparing the seasonal rhythm of cholera-prevalence with that of rainfall, we find that the months for the former also fall into three groups of maximum, minimum and intermediate prevalence. The groups in this case, however, do not precisely correspond with those of rainfall, for whilst that of maximum includes four months, that of minimum includes three only, and the remaining five months form the intermediate group.

Table XXV shows the relation which the three groups of months, arranged in reference to rainfall and prevalence, bear to one another.

The minimum months of prevalence correspond with three of maximum rainfall; the maximum months of prevalence coincide with one of minimum and three of intermediate rainfall; the intermediate months of prevalence coincide with three of minimum, one of intermediate, and one of maximum rainfall. The correspondence between special phenomena of prevalence and special periods of rainfall is much less distinct than that between the phenomena of atmospheric humidity and of prevalence. Beyond the fact that the three months of minimum prevalence correspond with three of the period of maximum rainfall, there is nothing indicating any special relation either direct or inverse between the two phenomena.

TABLE XXV.

Comparison of periods of maximum, minimum, and intermediate Rainfall, and Cholera-prevalence.

	Rainfall.	Cholera.
Maximum	June.	February.
	July.	March.
	August.	April.
	September.	May.
Minimum	November.	
	December.	July.
	January.	August.
	February.	September.
Intermediate	March.	January.
	April.	June.
	May.	October.
	October.	November.
		December.

Taking the period of maximum prevalence, we find that it ranges over one month of minimum and three of intermediate rainfall; and if we compare the phenomena of these months more closely, the want of any direct definite relation between them is even more distinctly brought out.

TABLE XXVI.

Comparison of Rainfall and Cholera-prevalence from February to May.

Months.	Feb.	March.	April.	May.
Rainfall	0·83	1·28	2·49	5·46
Cholera	12,612	19,558	24,040	16,641

Taking the data up to April, there might be some grounds for ascribing significance to the correspondence between increased rainfall and increased prevalence; but when we come to May, we find a continued increase of rainfall—and an increase, too, fairly comparable with those preceding it in amount—coincident with marked decrease in place of increase in prevalence. A similar want of correspondence is manifest in the data of the months of intermediate prevalence.

TABLE XXVII.

Comparison of the Rainfall with the amount of Cholera in the months of Intermediate Prevalence.

Months.	June.	October.	Nov.	Dec.	January.
Rainfall	12·13	5·61	0·66	0·24	0·44
Cholera	8,556	8,016	11,112	10,334	9,105

Here, on comparing June and October, there is diminished rainfall and diminished prevalence; on comparing October and November, diminished rainfall and greatly increased prevalence; and on comparing November, December and January, what is practically unaltered rainfall with considerable decrease in prevalence.

There are other conditions in reference to rainfall, however, which remain to be considered. As yet the total fall per month alone has been dealt with, but it is also necessary to inquire into the distribution of the fall, into questions relative to the average number of rainy days in each month, the average fall on each of these and the average of the heaviest falls occurring within 24 hours in each month.

The following table, constructed on the data furnished by the observations at the Surveyor General's Office, shows the average number of days on which rain fell in each month of the past 21 years, together with the average per day of fall, and the averages of the heaviest falls in 24 hours.

TABLE XXVIII.

Average Characters of the Rainfall of each month (21 *years*).

Month.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Average rainfall	0·73	0·11	0·46	1·07	1·61	2·07	5·27	12·90	13·02	14·27	10·43	5·38	0·73
Average days of rainfall ...	2·6	0·71	2·3	3·1	4·9	7·9	13·4	20·7	25·7	26·0	22·1	9·8	2·6
Average fall per day of rain ...	2·28	0·015	0·34	0·2	0·32	0·26	0·39	0·62	0·5	0·54	0·47	0·6	0·28
Average of highest falls ...	0·97	0·40	0·52	0·91	1·09	0·92	1·52	3·81	2·92	3·32	2·42	1·97	0·97

These data regarding the characters of the rainfall in different months fail to show any correspondence between the phenomena of rainfall and prevalence beyond that already indicated by the quantitative data alone. They show the same fact of the coincidence of minimum prevalence with maximum rainfall, but with this all indication of the existence of any definite relation between the two sets of phenomena ceases to present itself. At one time—February and March—there is increase in the average amount of individual falls with increased prevalence; at another—November

—there is decrease in the amount of individual falls with increased prevalence, and at a third—May—there is increase in the amount of individual falls with decreased prevalence.

There is nothing in the entire series of data regarding the quantitative and qualitative characters of the rainfall at different times justifying a belief that it exerts any direct action either in producing or diffusing the essential cause of cholera, but, on the other hand, there is some evidence that excessive rainfall exerts a directly opposite action.

(e) Level of soil-water.

TABLE XXIX.

Comparison of Average monthly Water-level (6 years) and Cholera prevalence.

	Month.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Average water-level ...		11'·5	12'·9	13'·8	14'·2	14'·4	14'·6	14'·7	14'·0	12'·2	9'·6	8'·2	9'·7	11'·5
Cholera.	(Macpherson) ...	8,323	8,159	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323
	(Payne) ...	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789
	Total ...	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112

The above table and the diagram below show the average monthly water-level at the Alipore Jail, where observations on this point have been conducted since 1870. The diagram is constructed on a scale allowing one degree to every 6 inches, and the line showing the fluctuations in level is, as in the diagrams of humidity and rainfall, drawn in a reverse direction, rise on the diagram corresponding to actual fall, and fall to rise of the water.

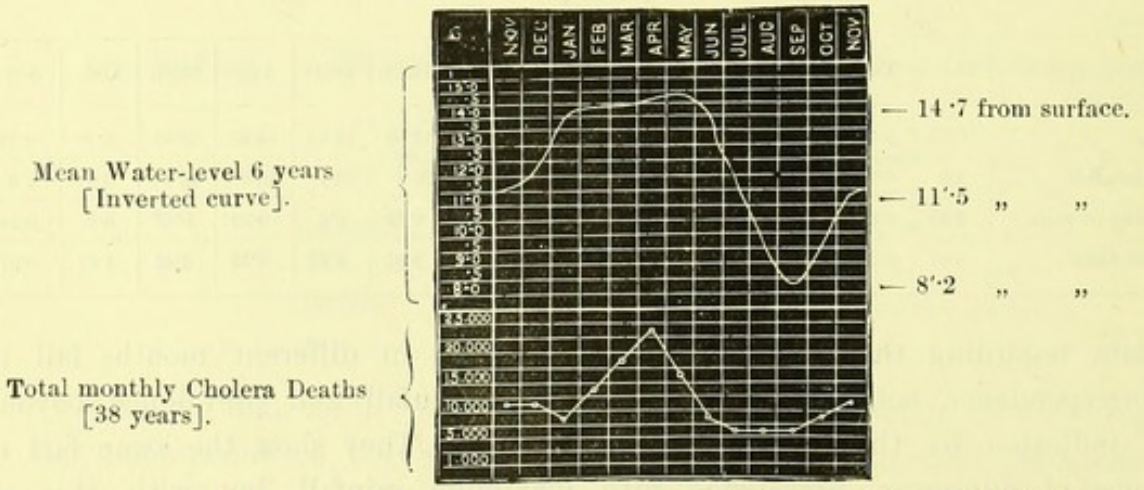


DIAGRAM 6.—Average Water-level and Cholera-prevalence in Calcutta.

The average water-level for the entire year is 12'·4. The average annual fluctuation in level is 6·4.

The following tables show the amount of rise in each year, the amount of fall from one year to another, and the relations of the lowest water-level of each year to one another, taking that of 1870 as zero.

TABLE XXX.

Amount of fluctuation from lowest to highest level in each year from 1870 *to* 1876.

Year.	1870.	1871.	1872.	1873.	1874.	1875.	1876.
Rise in water...	7′·0	8′·2	4′·4	5′·0	6′·8	5′·9	7′·9

The greatest rise during the period (8·2) occurred in 1871, the second in order (7·9) in 1876. The minimum rise (4·4) occurred in 1872.

TABLE XXXI.

Amount of fluctuation from highest level of one year to lowest level of the next.

Year.	1870-71.	1871-72.	1872-73.	1873-74.	1874-75.	1875-76.	1876-77.
Fall in water-level	6′·1	9′·0	4′·6	5′·1	6′·0	6′·7	7′·4

The greatest fall occurred in 1871-72, the next greatest in 1876-77, that is the greatest falls succeeded the greatest rises. The least falls also followed the least rises.

TABLE XXXII.

Comparative level of the water when farthest from the surface in each year from 1870 *to* 1877.*

Year.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	1877.
Comparison of lowest water-level	0·0	+ 10″	+ 1″	− 3″	− 5″	+ 3″	− 5″	0·0

The soil-water in 1871 was about 10″ nearer the surface when at its lowest than it was in 1870. In 1872 it was 1″ nearer the surface than in 1870. In 1873 and 1874 it was 3″ and 5″ lower than in 1870; in 1875 it was 3″ higher; in 1876, 5″ lower; and in 1877 it attained the same level as in 1870.

The averages show that the water is nearest the surface in September, and thereafter

* The *plus* sign indicates elevation above the level of 1870; the *minus* sign the reverse.

falls steadily, until it reaches a maximum depression in May, from which it again rises rapidly to maximum elevation. There is a considerable amount of coincidence apparent between the lines in the diagram indicating the course of the phenomena of depression of water-level and cholera prevalence. The period of maximum prevalence coincides with part of the period of maximum depression of the water-level, and one of the months of minimum prevalence with the month of minimum depression. When, however, the data are more minutely examined, the coincidence is found to be a general one only, and numerous divergencies between the courses of the two phenomena present themselves. For example, the average maximum depression of water-level occurs in May; but the prevalence of May is much less than that of April. There is, also, a continued fall in water-level in December and January, coincident with the diminution of prevalence occurring at that time. In fact, very much the same failures in coincidence are encountered here as in the comparison of the course of atmospheric humidity with cholera prevalence; and though we may again have recourse to the conditions of temperature as possibly accounting for the phenomena of December and January, we still require a satisfactory explanation for those of May.

Whilst the prevalence of cholera in Calcutta is associated with a low level of the soil-water, the data very clearly show that the absolute water-level, in itself, is of no importance. This cannot be better demonstrated than by comparing the average water-level and prevalence of July, October, and November.

TABLE XXXIII.

Comparison of Water-level and Cholera Prevalence in July, October, and November.

	July.	October.	November.
Water-level (average 6 years)	12′·2	9′·7	11′·5
Cholera (26 years)	5,297	8,016	11,112

October and November, whilst showing a prevalence much greater than that of July, have a considerably higher water-level than it has. If, then, the concurrence of low water-level and high prevalence of cholera in Calcutta be more than a mere coincidence,—if any casual relation exist between the two phenomena,—it cannot be a direct simple one, dependent on the mere mass of water in the soil.

Before leaving the subject, it may be well to look into the facts regarding the fluctuations of water-level, compared with those of actual prevalence, during the period in which the observations have been carried on.

Diagram 7 shows the monthly averages of water-level and rainfall since April 1870, together with the relative annual prevalence of cholera reckoned from the November of one year to the October of the next.

The entire period has been sub-divided from November to November, both to render the diagram uniform with those of the general averages, and also because November really forms a more natural beginning of the year in respect to cholera in Calcutta than January does. The prevalence during each annual period has been calculated from the figures in Dr. Payne's table.

The only point in the diagram deserving special notice here is, that it shows that the two years of the period which were distinguished by minimum prevalence of cholera, 1871 and 1872, were both years in which there was relatively slight depression of the water-level, succeeding seasons in which there had been excessive elevation of it. The minimum of depression and the maximum of elevation both occurred in 1871: the

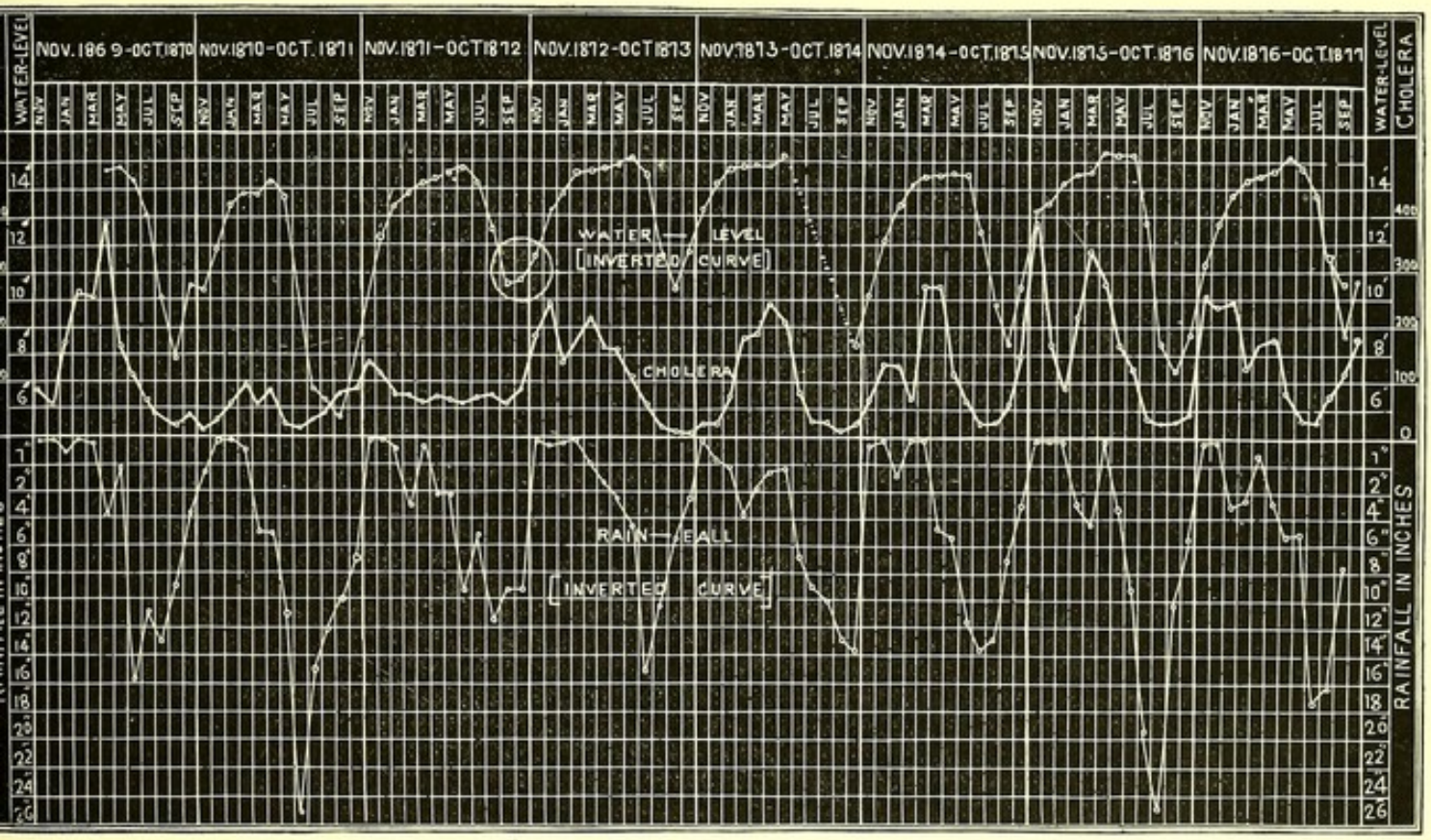


DIAGRAM 7.—The monthly fluctuations in Water-level and Cholera-prevalence in Calcutta, together with the mean monthly Rainfall, since 1870. [The water-level and rainfall-curves inverted.]

minimum succeeded a season in which the elevation was the third highest for the period: the maximum preceded one in which the depression was the third smallest. Further than this, however, no special coincidence can be traced between the phenomena of water-level and prevalence; but the fact that the season of 1873-74 was one of low prevalence for the period again shows that mere depression of water-level, mere diminution of the bulk of water in the soil, is insufficient, in itself, to secure prevalence.

One result of the observations has been to show that the water-level in Calcutta cannot be accurately estimated from the data of rainfall alone, and more especially from those of total annual rainfall. The distribution of the rain throughout the year must

TABLE XXXIV.

Data of Rainfall, Humidity, Temperature and Water-level, 1870 *to* 1876.

Months.	1869-70.						1870-71.						1871-72.						1872-73.						1873-74.						1874-75.						1875-76.					
	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.	Rainfall of previous season.	Rainfall.	Humidity.	Temperature.	Lowest water-level.	Highest water-level.
	"	"	'	°	' "	' "	"	' "	'	°	' "	' "	"	"	'	°	' "	' "	"	"	'	°	' "	' "	"	"	'	°	' "	' "	"	"	'	°	' "	' "	"	"	'	°	' "	' "
November ...	67".6	0·0	66	73·3			55".60	1·22	77	75·9			93".31	0·0	71	75·8			48".94	0·02	73	76·3			44".42	0·14	67	75·6			62".22	0·12	73	74·9			60".01	0·0	68	73·7		
December ...		0·0	68	63·5				0·0	70	66·5				0·0	70	69·0				0·09	73	70·0				0·82	69	69·9				0·0	67	67·1				0·0	69	69·1		
January ...		0·77	35	67·9				0 0	67	67·6				0·22	73	68·8				0·0	69	68·0				0·94	71	66·4				1·2	75	66·4				0·0	65	67·8		
February ...		0·0	60	74·2				0 75	67	74·3				2·82	70	72·5				0·0	64	73·9				3 77	73	72·2				0·0	62	72·0				2·93	60	73·1		
March		0·03	58	81·0				5·41	68	79·4				0·21	65	82·7				1·18	64	79·8				1·94	64	78·2				0·0	70	81·7				4·36	70	81·1		
April		4·03	64	84·1				5·72	77	82·7	13·11			1·83	65	85·6				1·84	72	84·2				1·20	70	85·1				4·18	69	85·4	14·6			0·20	67	86·2	15·2	
May		0·92	70	87·7	14·9			11·08	78	83·3				1·99	72	86·8				3·78	69	86·6				1·16	72	87·1	15·2			5·24	73	84·3				2·93	73	86·5		
June		16·09	80	84·7				25·35	88	82·7				9·45	80	85·1	14·8			4·30	75	87·9	15 0			6·89	82	83·7				11·83	84	84·0				9·32	80	85·6		
July		10·90	85	83·9				15·93	87	82·5				5·55	86	83·1				14·76	87	83·4				8·89	83	84·0				13·90	86	83·2				19·39	88	82·7		
August... ...		12·92	88	82·4				12·11	88	82·9				11·52	88	83·1				10·23	86	83·3				10·19	86	82·9				12·64	87	82·7				24·85	86	83 0		
September ...		9·01	84	83·2		7·10		9·93	87	82·5		5·9		8·42	85	83·1		10·6		5·82	83	84·3		10·1		12·67	86	82·9				7·41	86	82·8		8·7		10·26	86	82·9		7·5
October ...		3·93	82	82·4				7·03	77	81·6				8·93	81	81·4				2·40	71	82·0				13·71	82	81·5		8·6		3·42	75	81·3				5·80	79	79·7		

be taken into account. This, however, is not all that is required to secure a determination of the relations borne by the water-level in one year to that in another; for it is evident that the variation in the amount of loss by evaporation must importantly modify the effect of the addition by rainfall. Even if the data of temperature and atmospheric humidity be taken into consideration along with those of rainfall, only very unsatisfactory results are obtained, compared with those furnished by direct observation. That this is the case is very distinctly shown by the preceding table (XXXIV), showing the particulars of rainfall, temperature, and humidity, from 1870 to 1876, arranged, as far as possible, in a way to facilitate their application to questions of water-level.

(f) Soil-temperature.

TABLE XXXV.

Comparison of average Monthly Soil-temperature (3 years) and Cholera-prevalence.

		Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Soil-temperature.		78·1	75·4	72·6	73·1	75·4	78·8	80·9	82·3	82·3	81·7	81·4	81·1	78·1
Cholera.	(Macpherson) ...	8,323	8,159	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323
	(Payne) ...	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789
	TOTAL ...	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112

The diagram, in addition to the lines indicating soil-temperature and cholera-prevalence, contains a third line of the average atmospheric temperature, in order to allow of ready comparison of the relations of the air above and within the soil in this respect.

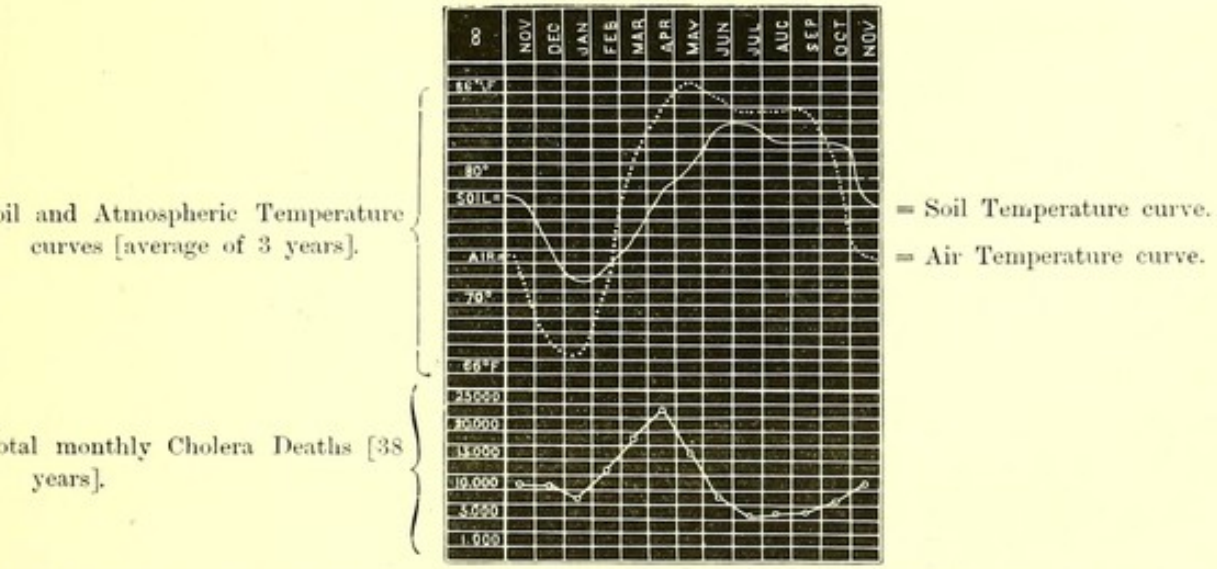


DIAGRAM 8.—Average Soil-temperature at 6 feet below the surface, and Cholera-prevalence.

The data regarding temperature are those of the soil at a depth of six feet from the surface, and therefore represent the conditions of a stratum towards the lower portion

of the layer of soil, which lies permanently above the soil-water. The mean temperature for the year is 78·5.* The minimum soil-temperature occurs in January; the maximum in June and July. The temperature exceeds that of the atmospheric air in the months of November, December, and January; falls far short of it during March, April, and May; and is almost equal to it during the remaining months. These facts will receive notice again; but in the meantime it may be pointed out that, in so far as conditions of temperature are concerned, soil-ventilation is favoured during November, December and January; obstructed during March, April and May; and almost in equilibrium during the remaining months.

Comparing the data of soil-temperature and cholera-prevalence, we find that the great maximum of prevalence in April and the minor elevation in November both occur when the soil-temperature is between 78° and 79°, the actual figures being 78°·8 and 78°·1, or at a mean elevation. Here, however, the coincidence ceases; for the increase of soil-temperature after April, and the decrease after November, are both associated with decreased cholera-prevalence. Whether the fact really be of any important significance or not, it is, at all events, worthy of note that such a coincidence should be present in reference to these two months; for in other respects they differ from one another considerably. The only other condition in which they tend to agree is the atmospheric humidity: the atmospheric temperature, rainfall and water-level all present important divergencies. The period of minimum prevalence occurs along with that of maximum elevation of temperature; but the same elevation extends beyond it in both directions, commencing and terminating in June and October, two months

* It may be of interest to compare the figures illustrating the relations of telluric and atmospheric temperature in Calcutta with those of a locality where the temperature is very different. The following table shows the mean temperature of the air and of the soil at a depth of 30·2 metres in St. Petersburg for each month of 1875 (*Annalen des Physikalischen Central Observatoriums*—Jahrgang, 1875):—

TABLE XXXV (*a*).

Mean Monthly Temperature of Air and Soil of St. Petersburg.

1875.	Mean Temperature (Fahrenheit).	
Months.	Air: mean = 35°·0.	Soil: mean = 44°·3.
January	6°·5 Fahr.	44°·0 Fahr.
February	17°·0	41°·0
March	18°·5	39°·0
April	30°·2	37°·5
May	47°·5	37°·4
June	59°·7	39°·8
July	65°·7	44°·8
August	58°·8	49°·9
September	48°·0	51°·8
October	35°·0	51°·5
November	24°·0	48°·5
December	8°·6	44°·8

of medium prevalence. The fact, that a marked fall in the soil-temperature occurs from November to the minimum in January, is of importance in connection with the questions previously alluded to in the diminished prevalence during the same period. We now see that if temperature really exert any influence, that of the soil must be considered as well as that of the atmosphere above it; and is even, perhaps, in this case of more importance, as the course of the phenomena of soil-temperature in December and January corresponds more closely with the course of the prevalence than that of the atmospheric temperature does.

(g) Carbonic acid of the Soil-air—Soil-ventilation.

TABLE XXXVI.

Comparison of the monthly average of Carbonic Acid [at 6 feet] with Cholera-prevalence.

		Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.
Relative amount of Co_2 in Soil-air ...		5	5	5	3	1	1	2	2	2	5	6	5	5
Cholera.	(Macpherson)	8,323	8,159	7,150	9,346	14,710	19,382	13,335	6,325	3,979	3,440	3,935	6,211	8,323
	(Mayne) ...	2,789	2,175	1,955	3,226	4,848	4,658	3,306	2,231	1,318	1,684	1,543	1,805	2,789
	TOTAL ...	11,112	10,334	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11,112

The diagram, No. 9, on the following page, in this case is constructed from confessedly very imperfect materials. Our data regarding the amount of carbonic acid in the soil-air are as yet very limited, and those employed in the present instance are derived from observations carried out for little more than a year—from July 1873 to August 1874—after which date the observations were unavoidably interrupted until May 1877.* Certain facts have, however, been already ascertained regarding the course of the fluctuations in amount of carbonic acid in the soil-air, so that the data of 1873-74 may be employed as illustrating the more general phenomena, although not constituting rigid examples of the precise conditions actually present in individual years.

* We are indebted to Mr. Henry F. Blanford, Meteorological Reporter to the Government of India, for having made arrangements for the exposure of tubes charged with baryta solution at certain of the larger Meteorological stations. The requisite apparatus has already been provided at Allahabad, Lucknow and Delhi, and observations are now conducted at these places through the assistance of Mr. S. A. Hill, B.Sc., Dr. Bonavia and Assistant-Surgeon Radha Kishen. The tubes charged with the baryta solution are sent by post to the different stations at short intervals, returned after exposure, and the amount of carbonic acid determined.

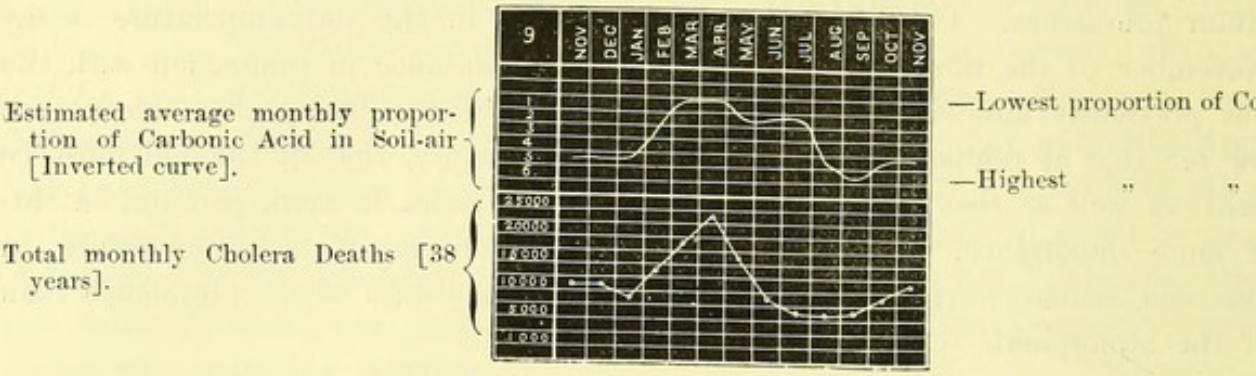


DIAGRAM 9.—Monthly averages of Carbonic Acid in the Soil-air (6 feet below the surface) and Cholera-prevalence.

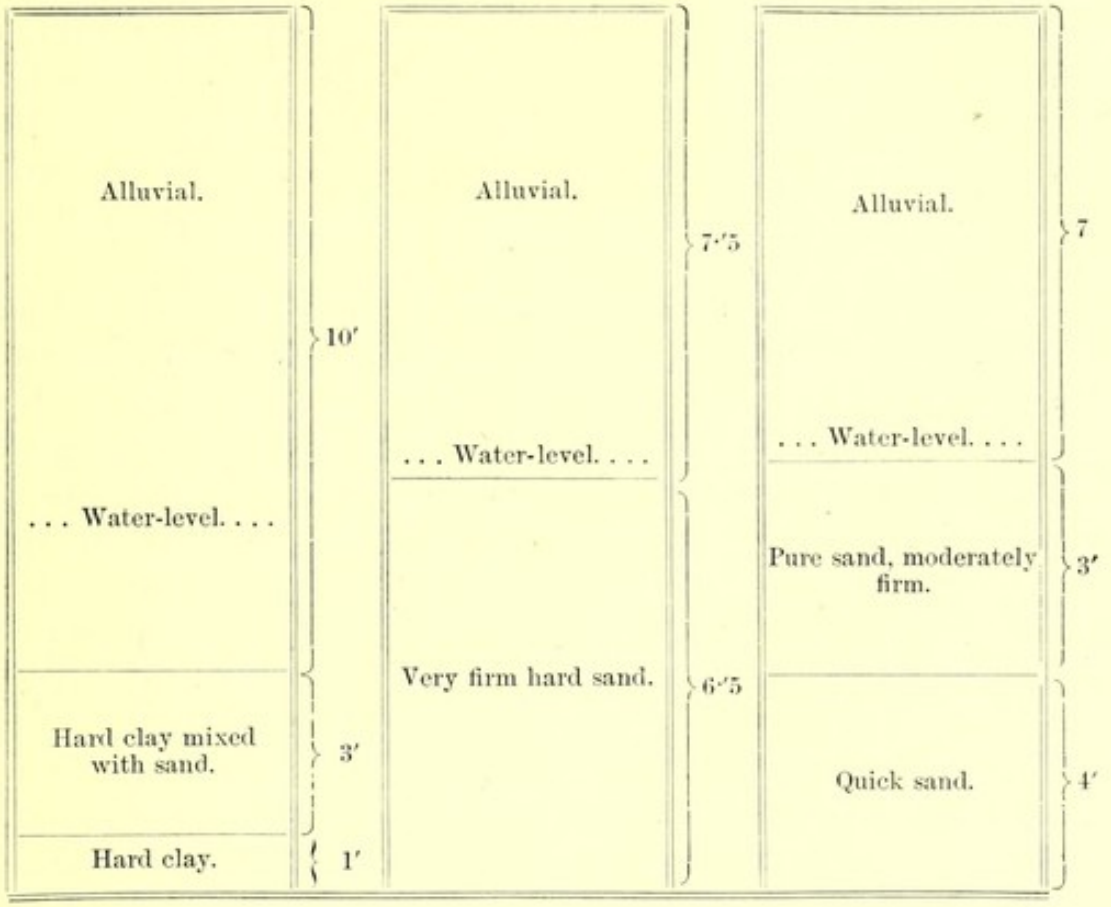
The line indicating the carbonic acid in the diagram is reversed like those in the diagrams of humidity, rainfall and water-level, and the figures in the table are to be regarded as only representing the relations borne by the amounts of carbonic acid to one another, and not the absolute quantity present.

Taking the data as they stand, we find that, during November, December and January, the amount of carbonic acid is high. In February a considerable decrease occurs, and the minimum for the year is reached in March and April. During May a slight increase occurs, continued through June and July, and followed by a rapid rise in August to the maximum in September, after which a decrease occurs, reducing the average for October to an equality with that for August on the one hand, and for November, December and January on the other.

The first question which presents itself here is,—What are we to regard these fluctuations as representing? We believe that they are to be regarded as affording an index to the varying degrees of soil-ventilation present at different times of the year; in other words, to the varying degree in which emanations escape from the soil into the atmosphere at different times of the year.

The fluctuations in the amount of carbonic acid in the soil-air must be due to one or other of two causes: (1) variation in the amount produced at different times; (2) variation in the degree of accumulation of what is formed—variation in the amount retained in the soil. The phenomena of fluctuation in Calcutta appear to be mainly determined by the latter agency. The most conspicuous fluctuations during the course of the year are the rapid decrease of carbonic acid during the months of February and March and the rapid increase during August and September. The coincidence of increased carbonic acid with the occurrence of rainfall has been amply confirmed by the observations of the current year, and the phenomenon is only explicable as due to the action of the rain upon the ventilation of the soil. That rainfall acting on a finely-textured soil like that in Calcutta should produce such an effect, is only what might have been fairly assumed independent of experimental evidence. The surface-soil of Calcutta consists of layers of loam, sand and clay, but the depth and distribution of

these varies greatly even within areas of very limited extent. This is well shown in the following diagram, illustrating the nature of the strata encountered in three of the borings made in 1875 in the site of the India Museum :—



It is clear that water must tend to close the pores in such a soil so far as it penetrates, and, when added from above as by rainfall, must therefore tend to interpose an impermeable partition between the air of the atmosphere and that contained in the soil beneath the moistened layer.

Water deposited on soil like that in Calcutta takes long to penetrate to any distance from the surface—a fact which must be familiar to all who have had opportunities of observing the sections presented by fresh excavations during the early part of the rainy season—and the increase in amount of carbonic acid begins to occur long ere the water has reached the stratum from which the air containing it is derived. This alone is almost conclusive in favour of the increase at this time being due to accumulation, but there are other grounds for regarding the degree of soil-ventilation as the principal factor regulating the fluctuations in the amount of carbonic acid throughout the year.

The temperature of the soil cannot be regarded as the determinant, as we find the amount of carbonic acid on the one hand varying at different times independent of corresponding variations in soil-temperature, and on the other hand remaining constant

in spite of considerable variations in temperature. The amount of carbonic acid present in November, December and January greatly exceeds that present in April, a month in which the soil-temperature is almost equal to that of November, and considerably higher than that in the other two months. But while the temperature of the soil in November and April is almost equal, the amount of moisture in the soil, and consequently of soil-ventilation, is very different in the two months, the former of which immediately succeeds the cessation of the rains, the latter following a long period of almost total rainlessness. It is, moreover, only by explaining the phenomena of fluctuation as due to soil-ventilation that the results of the Indian observations are brought into accordance with those attained in Europe.

The results of the European observations have been to show that the maximum of carbonic acid in the soil-air occurs coincidently with the maximum temperature of the upper strata of the soil, but in Calcutta the maximum of carbonic acid is clearly connected with rainfall and independent of temperature. In Europe the rainfall is distributed throughout the entire year; in India it is concentrated into a few months; in Europe the fluctuations in carbonic acid in the soil-air probably correspond with variations in the amount formed, but in many parts of India the variations in amount of formation are almost entirely obscured by the effects of the varying degrees of soil-ventilation, although certain phenomena, such as the increase of carbonic acid during May and June in Calcutta, may be a partial indication of their existence.

On proceeding to compare the phenomena of cholera-prevalence with those of soil-ventilation as indicated by the carbonic acid of the soil-air, it appears that the maximum of prevalence coincides with the maximum of soil-ventilation and the minimum of prevalence with obstructed soil-ventilation. Taking individual months, however, the correspondence between the course of the two phenomena is not close or uniform, for we find the same degree of soil-ventilation indicated for August, October, November, December and January; whilst the cholera-prevalence of the same months varies widely, and a similar phenomenon is presented in May, June and July.

Whether the coincidences between the variations in soil-ventilation and cholera-prevalence indicate any essential connection between the two phenomena or not, there can be no doubt regarding the importance of the observations demonstrating their existence. They show that, in estimating the influence of the rainy season on conditions of health, its action in effecting soil-ventilation cannot be left out of consideration. Until it be conclusively demonstrated that all emanations proceeding from the soil are inert, the presence of any influences obstructing or facilitating their escape deserves careful consideration in any attempts at the explanation of the phenomena of disease as related to season. Hitherto rain has only been regarded as affecting health through the agency of the water supply or its action in washing the surface of the soil, but its relation to soil-ventilation has almost entirely escaped notice. This has, no doubt, arisen from the fact that the subject has been mainly studied in regions with climates like that of Europe, in which the rainfall is uniformly distributed throughout the year,

and in which therefore its influence on soil-ventilation is also uniformly distributed. Enough has, however, been shown here to prove that, in tropical climates at all events, the influence of rain on health cannot be regarded as necessarily solely exerted through such channels.

CHAPTER III.

PHYSICAL CHARACTERISTICS OF THE DIFFERENT SEASONS OF CHOLERA-PREVALENCE IN CALCUTTA.

It has been already pointed out that the year may be divided into three seasons, according to the degree of cholera-prevalence. During one of these seasons the prevalence greatly exceeds the average, during another it falls far short of it, and during the third it ranges on either side of it. The season of maximum prevalence includes the months of February, March, April and May; that of minimum prevalence, the months of July, August and September; and that of medium prevalence, the remaining five months of the year. In order to facilitate the comparison of the main meteorological characters of these three seasons, it will be well at first to leave two of the months of the season of medium prevalence out of consideration. These are June and October, when the conditions are greatly complicated by the transitional character of the months as periods ushering in and concluding the rainy season, June partaking of the characters of the hot and rainy seasons, and October of those of the rainy and dry ones. Leaving them out, we find the meteorological characters of the individual cholera seasons to be the following:—

TABLE XXXVII.

Physical characteristics of the individual months of the seasons of maximum, minimum and medium Cholera-prevalence in Calcutta.

Seasons of Prevalence.	Medium.			Maximum.				Minimum.		
Meteorological conditions.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	July.	Aug.	Sept.
Atmospheric Pressure ...	29·980	30·030	30·011	29·948	29·856	29·757	29·665	29·545	29·608	29·689
„ Temperature	74°·9F	68°·1	67°·7	73°·0	80°·5	84°·7	86°·2	83°·5	83°·1	83°·3
„ Humidity ...	71	68	68	68	67	63	75	87	88	87
Rainfall	0″·66	0″·24	0″·44	0″·83	1″·28	2″·49	5″·47	12″·64	13″·71	10″·17
Water-level	11′·5	12′·9	13′·8	14′·2	14′·4	14′·6	14′·7	12′·2	9′·6	8′·2
Temperature of the soil ...	78°·1F	75°·4	72°·6	73°·1	75°·4	78°·8	80°·9	82°·3	81°·7	81°·4
Carbonic acid in the soil-air	5	5	5	3	1	1	2	2	5	6

TABLE XXXVIII.

Average physical characters of the three seasons of Cholera-prevalence, June and October being excluded from the months of medium prevalence.

Meteorological conditions.	Seasons of prevalence.		
	Medium.	Maximum.	Minimum.
Atmospheric Pressure	30·007	29·806	29·614
„ Temperature	70°·2F.	81°·1	83°·3
„ Humidity	69	70	87
Rainfall	0″·44	2″·51	12″·17
Water-level	13′·1″	14′·4″	10′·0″
Temperature of the soil	75°·3F.	77°·0	81°·8
Carbonic acid in the soil-air	5	1	4

The season of minimum prevalence is, according to these data, characterised by low atmospheric pressure, high atmospheric and soil temperatures, by extreme atmospheric humidity and rainfall, by elevation of the water-level, and by obstructed ventilation of the soil as indicated by the amount of carbonic acid in the soil-air. The season of medium prevalence is characterised by high atmospheric pressure, low atmospheric and soil-temperature, by minimum humidity and rainfall, by depression of the water-level, and by obstructed ventilation of the soil. The season of maximum prevalence shows characters occupying an intermediate position in regard to those of the other two seasons except in so far as its water-level and soil-ventilation are concerned. The former of these is at a maximum of depression, the latter at a maximum of activity. According to these data, the depression of the water-level and the increase of soil ventilation are the only phenomena which reach a climax during the season of maximum prevalence of cholera.

When June and October are included with the other months of medium prevalence the results of the comparison are slightly modified.

TABLE XXXIX.

Average characters of the seasons of Medium, Maximum and Minimum prevalence, of Cholera.

Meteorological conditions.	Seasons of prevalence.		
	Medium.	Maximum.	Minimum.
Atmospheric Pressure	29·880	29·806	29·614
„ Temperature	75°·4F.	81°·1	83°·3
„ Humidity	74	70	87
Rainfall	3″·81	2″·51	12″·17
Water-level	12′·7	14′·4	10′·4
Soil-temperature	77°·9F.	77°·0	81°·8
Carbonic acid in the soil air	4	1	4

The ventilation of the soil and the depression of the water-level are, as before shown to be, greatest during the season of maximum prevalence, but the latter is now also characterised by the minimum humidity, rainfall and soil-temperature.

Such are the results arrived at on comparing the entire seasons of cholera-prevalence; it remains to be seen how far these are confirmed by the comparison of typical months selected from the individual seasons. November, April and August are the months indicated by the statistics as those of actual medium, maximum and minimum prevalence during the course of the entire year, and are therefore those selected for comparison.

TABLE XL.

Comparison of the characters of the months of actual Medium, Maximum and Minimum Cholera-prevalence.

Meteorological conditions.	November (medium).	April (maximum).	August (minimum).
Atmospheric Pressure	29·980	29·757	29·608
„ Temperature	74°·9F.	84°·7	83°·1
„ Humidity	71	73	88
Rainfall	0″·66	2″·49	13″·7
Water-level	11′·5	14′·6	9′·5
Soil-temperature...	78°·1F.	78°·8	81°·7
Relative amount of carbonic acid in the soil-air ...	5	1	5

Here, again, the period of maximum prevalence is characterised by excessive soil-ventilation and depression of the water-level. The other results agree with those of the Table (XXXVIII) in which June and October are omitted, except that here the atmospheric temperature is higher in the maximum than in the minimum period, and that the amount of carbonic acid in the soil of the minimum period is now equal to, in place of slightly less than, that of the medium period.

In all the previous comparisons the maximum period has been uniformly distinguished from the others by two characters only—by depressed water-level and excessive soil-ventilation. On leaving the medium period of prevalence out of consideration, and comparing the maximum and minimum periods, it appears that the former is characterised by its higher atmospheric pressure, its lower atmospheric and soil-temperature, humidity and rainfall, and by its greater soil-ventilation and depression of the water-level. When the medium and maximum periods are combined and the year regarded as divided into two seasons, one of major and one of minor prevalence, the characters of these are as shown in the following table:—

TABLE XLI.

Comparison of the average monthly characters of the periods of Major and Minor Cholera-prevalence in Calcutta.

Meteorological conditions.	Period of major prevalence.	Period of minor prevalence.
Atmospheric Pressure	29·847	29·614
„ Temperature	77°·9F.	83°·3 F.
„ Humidity	72·5	87·
Rainfall	3″·23	12″·17
Water-level	13′·3	10′·0
Temperature of the soil	77°·5	81°·8
Relative amount of the carbonic acid in the soil-air	3	4

Here the combined periods of medium and maximum prevalence, as compared with that of minimum, are shown to be characterised by higher atmospheric pressure, by lower atmospheric and soil-temperature, by lower humidity and rainfall, and by greater ventilation of the soil and depression of the water-level. Taking the entire series of comparisons, it would appear that the conditions most closely connected with the seasonal prevalence of cholera in Calcutta are those of water-level and soil-ventilation. Both water-level and soil-ventilation appear, however, to be mainly determined here by the rainfall, so that the conditions of rainfall and prevalence must also be intimately connected. That they actually are so, is indicated by the coincidence of maximum rainfall with minimum cholera; and that the connection between them is not direct has been already shown by the results of the comparison of the data of rainfall and prevalence of individual months. If, then, rainfall exert any influence on the prevalence of cholera in Calcutta, it would appear that it must do so through the medium of its direct action on the conditions of the soil.

When we compare the characters of the months terminating the various seasons of prevalence with those of the months immediately succeeding them and ushering in the following seasons, very similar conclusions are arrived at.

The following table shows the characters of February compared with January, of May compared with June, of June compared with July, and of October compared with September. The month of minor prevalence is placed after the other throughout the sub-divisions of the table, and the results of the comparisons are separately stated in columns indicating, in regard to the various meteorological conditions, the increase or diminution occurring coincidently with decreased prevalence.

TABLE XLII.

Comparison of the characters of the months initiating and terminating the various seasons of Cholera-prevalence.

Meteorological conditions.	Months of maximum and medium.			Months of maximum and medium.			Months of medium and minimum.			Months of medium and minimum.		
	February.	January.	Change with decrease.	May.	June.	Change with decrease.	June.	July.	Change with decrease.	October.	September.	Change with decrease.
Atmospheric Pressure ...	29·948	30·011	+	29·665	29·550	−	29·550	29·545	−	29·831	29·689	−
„ Temperature	73°·0F	67°·7	−	86°·2	84°·9	=	84°·9	83°·5	−	81°·5	83°·3	+
„ Humidity ...	68	68	=	75	83	+	83	87	+	80	87	+
Rainfall	0″·83	0″·44	−	5″·46	12″·13	+	12″·13	12″·64	+	5″·61	10″·17	+
Water-level	14′·2	13′·8	−	14′·7	14′·0	−	14′·0	12′·2	−	9′·7	8′·2	−
Soil-temperature... ...	73°·1F	72°·6	−	80°·9	82°·3	+	82°·3	82°·3	=	81°·1	81″·4	+
Carbonic acid in the soil-air	3	5	+	2	2	=	2	2	=	5	6	+

Here we find minor cholera-prevalence invariably associated with relative elevation of the water-level, with either decreased or unaltered soil-ventilation, and with increased or unaltered atmospheric humidity. The remaining meteorological conditions accompanying it sometimes show an increase and at others a decrease, but the close connection of rainfall and prevalence is still very distinctly indicated.

The entire series of data at disposal do not point to any single meteorological condition as the determinant of the phenomena of the seasonal fluctuations in the prevalence of cholera in Calcutta. They indicate depression of the water-level, free ventilation of the soil, and a relatively low degree of atmospheric humidity as the conditions most influential in promoting the prevalence of the disease. When these conditions are simultaneously present, the maximum prevalence occurs, but one or other may be present at other times in very high degree without the prevalence necessarily showing a corresponding elevation. In February, March, April and May, all the favourable conditions are present, and the disease attains its maximum of prevalence; but in November, December and January, when, although the atmospheric humidity is very low, the water-level is relatively high, and the soil-ventilation obstructed, the prevalence does not nearly equal that of the former period. In June, again, as compared with May, there is a great diminution in prevalence, when our data regarding the carbonic acid in the soil-air do not warrant us in regarding the soil-ventilation as diminished, but at this time the atmospheric humidity is greatly increased, and the water-level undergoes a considerable elevation.

Although the water-level, soil-ventilation and humidity appear to be the most influential conditions in relation to cholera in Calcutta, there are certain phenomena of prevalence which they do not appear to be capable of explaining. During December and January the prevalence ought, in so far as influenced by them, to be higher in place of lower than in November. The question of the causation of the diminution in prevalence at this time has been already alluded to in those sections of this report treating of temperature and humidity, and it was then pointed out that the influence of temperature probably manifested itself in the phenomenon. The phenomena of prevalence presented by April and May are, perhaps, the most difficult of explanation of any throughout the entire course of the year. Here there is diminished prevalence with slight increase in the depression of the water-level, and with only very slight increase of atmospheric humidity or of obstruction to soil-ventilation. It certainly seems improbable that such small alterations in these conditions should be influential in producing such considerable effects. It must at the same time be borne in mind that, in so far as soil-ventilation is concerned, our data are very imperfect. They were obtained from observations conducted during an exceptional year, when the rainfalls of April and May did not stand in their normal relation to one another, that of the former month amounting to 1·20, and that of the latter to only 1·16 inches. There are good grounds for regarding rainfall as calculated to obstruct soil-ventilation, indeed we have experimental proof that it actually does so in Calcutta, so that the average difference between the soil-ventilation in April and May is probably greater than our data would lead us to believe.

The conditions which we are led to regard as most influential may be supposed to act in two ways in favouring prevalence of the disease. Assuming that cholera is produced by a specific material, or a combination of materials, the conditions of soil-ventilation, of water-level and humidity may influence either the diffusion and preservation of the material, or they may influence its production. The material may be produced either by chemical processes taking place independently of organic influences, or by processes dependent on such influences for their existence. If the latter be the case, conditions of soil-ventilation, of water-level and humidity, however influential in aiding development and diffusion of the material, may not alone be capable of determining the precise period of maximum production. This may be partially dependent on the intrinsic properties of the bodies in the course of whose organic changes the material is developed, and if so, a precise correspondence between the phenomena of prevalence and of the meteorological conditions favourable to it need not necessarily invariably occur. It is at present, however, premature to speculate more on the matter. The whole subject requires further investigation. All that can be done in the meantime is to suggest a possible explanation of certain of the obscure phenomena of cholera prevalence, and to indicate the extremely complex nature of the questions to be determined.

II.—CHOLERA IN THE ENDEMIC AREA GENERALLY.

CHAPTER I.

THE RELATION OF VARIOUS PHYSICAL PHENOMENA TO CHOLERA IN OTHER DISTRICTS OF THE ENDEMIC AREA IN THE BENGAL PRESIDENCY.

(a) Geographical limits and character of the soil of the Endemic area.

HAVING discussed the question of the relation of cholera to certain generally studied physical phenomena in Calcutta as fully as the statistical and other data seemed to warrant, we now propose applying the same process to such other parts of India as present a cholera-history more or less closely identical with that of Calcutta. It will not be necessary to treat the several stations which belong to this class with the same minuteness as Calcutta; nor indeed, were it desirable to do so, is there sufficiently precise information in existence regarding them to render such a description possible.

In his important work, "Cholera Epidemics of Recent Years," Dr. Bryden defines the region of endemic cholera in the Presidency of Bengal as "the basin having the hill-country east of the Brahmaputra for its eastern margin, and the Rajmahal and Cuttack hills for its western margin. Its northern limit is the terai of the Himalayas from Lower Assam on the east to the terai of the Purneah district on the west, and its southern limit is the sea border of the Bay of Bengal, from Pooree in the west, to beyond the mouth of the Brahmaputra in the east" (page 61).

In may be observed at starting that the history of cholera all over India presents one common feature, and that is that it can only be fairly regarded as endemic in such localities as manifest a close resemblance in the more superficial layers of their geological formation. This feature, it will be found, is more conspicuous than any of the other physical characters to which we shall have occasion to refer.

We have already indicated generally what characters the surface-soil of Calcutta presents. Mr. Henry F. Blanford in his *Physical Geography* describes it in a few words as a mixture of firm sand and clay with decayed animal and vegetable matter—loam, very much like the silt that settles from muddy river-water. Below this, at a distance of from 6 to 10 feet, comes a bed of stiff clay, and below this again a layer of peat resting on alternating layers of sand and clay.

Mr. Blanford tells us that many years ago a well was sunk in Calcutta to a depth of 481 feet through successive layers of sand, clay, peat and pebbles; that

at 380 feet was a layer of fresh-water shells resting on a bed of decayed wood, indicating that this must at one time have constituted the surface, but that it has since sunk and been covered by a soil formed by deposits from a river.

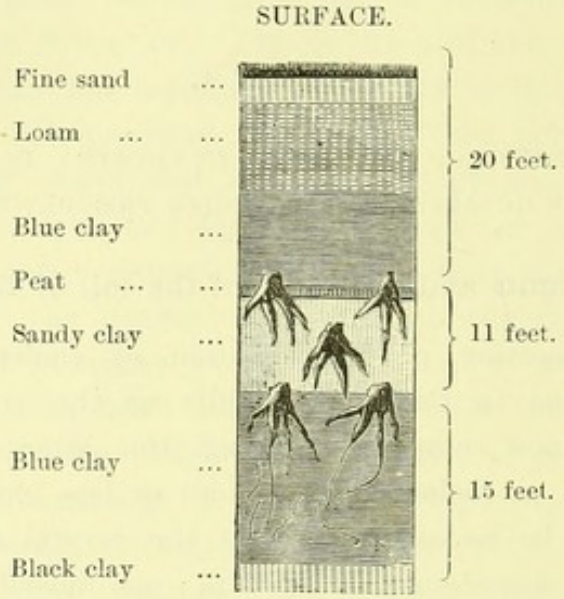


DIAGRAM 10.—A Section of ground exposed in a tank at Sealdah, Calcutta [H. F. BLANFORD].

Taken generally, it may be stated that the more the soil of a district in India approaches to the character here described, the more likely is it to be one whose inhabitants are more or less constantly liable to be affected with cholera.

This general statement regarding endemic cholera is not merely applicable to the districts which occupy the Gangetic plains of Lower Bengal, but also to certain parts of Oudh and the North-Western Provinces, as well as to similar plains which have been formed by the silt of the Godavery, the Mahanuddy, the Brahmaputra, and the Cauvery—in all of which areas cholera is more or less distinctly endemic.

We have selected certain localities of this area in which statistics have been collected for a long series of years from among those sections of the population regarding which care has been taken to attain fairly accurate particulars—namely, the European and Native troops and the prisoners. The data which these afford, although not sufficient to warrant definite conclusions as to the comparative healthiness of different stations, are yet sufficient to indicate with considerable exactness at what particular seasons of the year cholera is most prevalent.

A glance at the map of India, facing p. 205, will show that the area over which these selected stations are distributed is a very wide one, considerably larger than the whole of England and Wales. As there are some districts within the limits of this area considerably less prone to the disease than others, so are there districts in the Bengal Presidency beyond them in the larger towns of which cholera may also be said to be endemic, as for example Fyzabad and other towns in Oudh.

(b) Prevalence of cholera according to Monthly periods in the Endemic area, and the mean monthly Rainfall.

Applying the same principle to these endemic districts as was applied to Calcutta, we have collected the monthly cholera returns for several years past and compared them all, so far as the data available permitted, with the several meteorological and allied physical conditions. It is not deemed necessary to submit full details of these comparisons, as, taken together, they yielded closely similar results. As in Calcutta, so in these districts generally, the most characteristic physical phenomena with which the prevalence of cholera is associated all over the endemic area, are indicated by the fact that at most of the stations the disease is less prevalent during the height of the rains, or rather it would be, perhaps, more accurate to say that it attains its maximum when the depression of the sub-soil water is at its maximum, and consequently, in a general way, holds an inverse relation to the proximity of the sub-soil water to the surface, so long, of course, as the sub-soil water under observation is ascertained to lie over the first impermeable layer.

This is completely in accord with what all writers who have studied this subject specially have asserted. Dr. Bryden (op. cit., page 61), after describing the proximity of the water to the surface in the endemic area, and pointing out that vast tracts of land are annually submerged, writes: "It is with the inundation of these tracts that cholera disappears, and it is with their re-appearance that cholera re-appears."

In Table XLIII, on following page, will be found a monthly statement of rainfall and of all the cholera cases that have been registered among the European and Native troops and the Prisoners in all the principal stations distributed over the area which has just been referred to as furnishing meteorological phenomena and conditions of soil closely resembling those observed in Calcutta.

It will be noticed that, save in the case of Calcutta itself, no use has been made of the statistics which have been collected among the general population. This has been done because no sufficiently trustworthy records of vital statistics are at present in existence. As the data employed refer solely to communities of average uniform strength from year to year, regarding whom very accurate information is recorded, and as this information extends, in nearly all cases, over a considerable number of years, they suffice to indicate the time of year when cholera is most prevalent, especially when all the stations are taken together.

Taken month by month it will be seen that the dozen stations tabulated present considerable similarity. In nearly all of them it is in March, April or May that cholera prevalence is most marked, more especially in such of the stations as closely approximate to Calcutta in its physiography. When, however, we approach the borders of this territory—as, for example, at Dinapore, a station commonly left out

TABLE XLIII.

A Monthly Statement of Cholera in the Principal Stations of the Endemic Area among European and Native Troops and Prisoners for periods of from 23 *to* 51 *years, together with the average Monthly Rainfall.*

Stations.	Elevation in feet.	Number of years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Remarks.
CALCUTTA	18′															
Cholera	...	38	9,105	12,572	19,558	24,040	16,641	8,556	5,297	5,124	5,478	8,016	11.112	10,334	135,833	Total population.
Ditto (Fort William and Alipore) ...	...	551	94	211	560	525	359	264	240	119	147	152	204	121	2,996	European and Native Troops and Prisoners only.
Rainfall	...	*48*	*0·43*	*0·87*	*1·35*	*2·39*	*5·40*	*12·08*	*12·78*	*13·94*	*10·18*	*5·61*	*0·55*	*0·23*	*65·81*	
DUM-DUM	20′															
Cholera	...	51	19	36	65	88	159	67	43	170*	34	47	62	23	813	European and Native Troops and Prisoners.
Rainfall	...	*48*	*0·43*	*0·87*	*1·35*	*2·39*	*5·40*	*12·08*	*12·78*	*13·94*	*10·18*	*5·61*	*0·55*	*0·23*	*65·81*	Calcutta observations.
BARRACKPORE	20′															
Cholera	...	51	84	100	250	318	375	260	137	150*	120	274	229	152	2,449	European and Native Troops.
Rainfall	...	*48*	*0·43*	*0·87*	*1·35*	*2·39*	*5·40*	*12·08*	*12·78*	*13·94*	*10·18*	*5·61*	*0·55*	*0·23*	*65·81*	Calcutta observations.
CHINSURAH & HOOGHLY ...																
Cholera	...	51	81	141	137	342	226	128	120	142	237	222	133	130	2,039	Europeans and Prisoners.
Rainfall	...	*12*	*0·61*	*1·43*	*2·18*	*3·68*	*5·23*	*10·65*	*11·97*	*12·31*	*7·88*	*3·94*	*0·41*	*0·15*	*60·49*	
BERHAMPORE & MOORSHEDABAD	65′															
Cholera	...	23	42	69	530	263	84	50	90	58	51	89	52	69	1,447	European and Native Troops and Prisoners.
Rainfall	...	*18·20*	*0·45*	*0·92*	*1·03*	*2·17*	*3·99*	*9·76*	*9·73*	*9·91*	*9·30*	*5·83*	*0·17*	*0·08*	*53·34*	
BURDWAN	102′															
Cholera	...	23	33	5	21	72	66	53	35	34	35	41	7	8	410	Prisoners.
Rainfall	...	*14·16*	*0·67*	*1·10*	*1·58*	*2·80*	*4·51*	*11·07*	*12·44*	*11·78*	*8·51*	*5·40*	*0·24*	*0·52*	*60·62*	
DACCA	35′															
Cholera	...	23	11	18	62	60	29	26	20	12	11	28	50	29	356	Native Troops and Prisoners.
Rainfall	...	*15·16*	*0·64*	*0·74*	*1·51*	*6·33*	*9·40*	*13·46*	*12·70*	*12·05*	*8·52*	*5·02*	*0·71*	*0·04*	*71·12*	
MALDAH...	160′															
Cholera	...	23	2	5	2	15	10	2	4	2	0	0	3	11	56	Prisoners.
Rainfall	...	*18·20*	*0·46*	*0·85*	*0·86*	*1·86*	*3·21*	*9·85*	*10·16*	*9·56*	*10·71*	*4·50*	*0·18*	*0·40*	*52·60*	
DINAGEPORE	...															
Cholera	...	23	7	0	17	86	75	32	10	7	3	1	52	6	296	Prisoners.
Rainfall	...	*14·16*	*0·22*	*0·68*	*0·75*	*2·57*	*7·43*	*18·84*	*16·09*	*13·41*	*12·75*	*5·98*	*0·15*	*0·04*	*78·91*	
PURNEAH	125′															
Cholera	...	23	3	0	220	278	97	22	4	0	0	4	0	0	628	Prisoners.
Rainfall	...	*6·7*	*0·40*	*0·43*	*0·21*	*1·84*	*2·56*	*12·36*	*14·90*	*13·60*	*10·98*	*3·88*	*0*	*0·05*	*61·21*	
MIDNAPORE	108′															
Cholera	...	23	9	36	146	111	8	287	35	3	2	4	10	6	657	Prisoners(with Sepoys during three first years).
Rainfall	...	*11·13*	*0·72*	*0·46*	*1·54*	*1·67*	*5·49*	*11·43*	*11·60*	*10·93*	*8·66*	*6·14*	*0·43*	*0·01*	*59·08*	
DINAPORE	180′															
Cholera	...	23	46	91	346	672	702	355	403	329	182	137	234	55	3,552	
Rainfall	...	*17·19*	*0·65*	*0·49*	*0·25*	*0·30*	*1·32*	*6·87*	*9·77*	*8·51*	*7·47*	*2·63*	*0·13*	*0.15*	*38·54*	Patna Observatory.

* Of the 170 cases that have occurred at Dum-Dum during 51 years in the month of August, 113 occurred after the cyclone in 1859; and 50 of the Barrackpore cases at the same period.

of the "endemic" area in cholera maps—we find a tendency for the disease to push on into June.

Midnapore, again, deviates somewhat from the other stations in this group, in that it shows a high cholera rate in June, and in other ways. The bulk of the June cases, which constitute this excess, occurred in 1857 and 1860: 103 cases in the former year, and 140 in the latter. It may be remarked in passing, that, unlike the rest of the stations in the list, Midnapore, together with a great portion of the district in which it lies, is situate on laterite soil. Indeed, it is perhaps not quite correct to imply that the disease is endemic in this particular town, as it would appear that occasionally it is absolutely free of it.

There is an idea prevalent that cholera is less liable to occur in lateritic districts than in others in India. We do not know what grounds exist for the supposition, but it is a matter deserving of the attention of those who have opportunities for judging. This peculiar soil—a compound of clay and oxide of iron—is very porous, and possesses the property of hardening on exposure to the atmosphere. In some parts of India it is very general, being spread out in sheets over the surface, from a few inches to many feet in thickness.*

With regard to the particular month in which cholera may be said to manifest itself in its average intensity at these stations, it is found that no marked uniformity exists, the local *entourage* of each station being, as may readily be supposed, sufficiently distinct to modify the seasonal prevalence of the disease to this extent. On the other hand, to attempt to ascertain this by taking the mean of the monthly cases of the stations forming the group could hardly be deemed as sufficiently approximate to the truth to warrant any marked deviation from the usual mode of tabulating seasonal occurrences. Each station would require to be taken by itself, as was undertaken with regard to Calcutta.

Assuming the end of September to correspond with the average termination of the rains, October may be conveniently taken as the commencement of a season; and as more than 50 per cent. of the annual rainfall of this group of stations falls within four months, May to September, the year might even be divided into the wet and the, comparatively, dry season. On the whole, however, we have deemed it convenient to adopt the tri-seasonal divisions, commonly adopted by meteorologists in this country, *viz.*, January to May, June to September, and October to December, but taking the last-named division as the first, instead of the third.

Omitting the statistics of the general population of Calcutta from our calculations,

* Whilst these pages were passing through the press, we consulted the Civil Surgeon of this station (Dr. R. J. Mathew) regarding what appeared to us to be some inconsistencies in the course taken by the water-level, judging from the returns. The following extract from Dr. Mathew's reply is very interesting: "Midnapore was an unfortunate station to select for such observations, inasmuch as, owing to the porosity of the sub-soil and lower strata, two-thirds of the wells in the place are dry for nearly half the year, and during the rains a well will fill in one night, and in two days after, should there be no rain, will be found half empty."

we find that the dozen stations which form the group under consideration have during the last 20 to 50 years furnished 15,699 cases of cholera,* the monthly distribution of which is as follows:

TABLE XLIV.

Showing the Monthly prevalence of Cholera among Soldiers, Sepoys and Prisoners in twelve stations in Lower Bengal during varying periods up to 51 years.

	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	Total.
Cholera	999	1,036	610	431	712	2,356	2,836	2,190	154	1,141	1,026	822	15,699

In the second and third chapters (of I. pp. 216-242) we have entered with some fulness into the question of the relation which cholera prevalence holds with regard to the pressure, temperature and humidity of the atmosphere in Calcutta, and the remarks there made apply, with more or less force, to this group of stations; for the meteorology of the different places manifests a close resemblance, and data are not available to enable any but general comparisons to be made.

With regard to the conclusion arrived at, that the minimum of cholera agreed with low pressure, it will be noted that this takes place during the heavy rainfall of the wet season, so that for this and other reasons, as already intimated, it may be inferred that the influence exerted on the prevalence of the disease, if any, by atmospheric pressure, must probably be of an indirect character.

The coincidence of the maximum rainfall with the minimum cholera-prevalence is nearly as evident in most of the stations of this group as it was in Calcutta. This is evident whether the stations be studied individually (as may readily be done by the aid of Table XLIII.) or be studied as a group. This point will be more fully discussed further on.

(c) Prevalence of Cholera according to Seasons in Endemic Area: also the Rainfall.

As might be supposed, no satisfactory comparison can be instituted between data of monthly prevalence of cholera in communities of very different strengths by a mere tabulation of monthly results or even by a comparison of monthly ratios. Satisfactory comparisons may, however, be made by taking the *seasonal* ratios of the total number of cases which have occurred in individual stations. Such ratios are shown in the following table (XLV), together with the relation which exists between cholera and rainfall in Lower Bengal when studied by seasons.†

* Occasionally records of deaths only could be obtained.

† Whilst preparing these seasonal tables of rainfall, Mr. H. F. Blanford very kindly favoured us with a manuscript copy of his table of monthly rainfall, which is to appear in the forthcoming Report on the Meteorology of India, so that the figures represent the latest data available.

TABLE XLV.

The prevalence of Cholera according to Seasons, together with the Seasonal Rainfall at twelve stations in Lower Bengal.

STATIONS.	NUMBER OF YEARS.	OCTOBER TO DECEMBER.		JANUARY TO MAY.		JUNE TO SEPTEMBER.		Totals of cholera and of average annual rainfall.
		Cholera and rainfall (3 months).	Percentage of cholera and rainfall to annual totals.	Cholera and rainfall (5 months).	Percentage of cholera and rainfall to annual totals.	Cholera and rainfall (4 months).	Percentage of cholera and rainfall to annual totals.	
CALCUTTA—								
Cholera (General population) ...	38	29,462	**21·7**	81,916	**60·3**	24,455	**18·0**	135,833
Ditto (Barracks and Jails) ...	5—51	477	**15·9**	1,749	**58·4**	770	**25·7**	2,996
Rainfall	*48*	*6·39*	*9·7*	*10·44*	*15·8*	*48·98*	*74·5*	*65·81*
DUM-DUM—								
Cholera	51	132	**16·2**	367	**45·2**	314	**38·6***	813
Rainfall	*48*	*6·39*	*9·7*	*10·44*	*15·8*	*48·98*	*74·5*	*65·81*
BARRACKPORE—								
Cholera	51	655	**26·7**	1,127	**46·0**	667	**27·3***	2,449
Rainfall	*48*	*6·39*	*9·7*	*10·44*	*15·8*	*48·98*	*74·5*	*65·81*
CHINSURAH AND HOOGHLY—								
Cholera	51	485	**23·8**	927	**45·5**	627	**30·7**	2,039
Rainfall	*12*	*4·50*	*7·4*	*13·18*	*21·8*	*42·81*	*70·8*	*60·49*
BERHAMPORE AND MOORSHEDABAD—								
Cholera	23	210	**14·5**	988	**68·3**	249	**17·2**	1,447
Rainfall	*18—20*	*6·08*	*11·4*	*8·56*	*16·0*	*38·70*	*72·6*	*53·34*
BURDWAN—								
Cholera	23	56	**13·6**	197	**48·1**	157	**38·3**	410
Rainfall	*14—16*	*6·16*	*10·1*	*10·66*	*17·6*	*43·80*	*72·3*	*60·62*
DACCA—								
Cholera	23	107	**30·0**	180	**50·6**	69	**19·4**	356
Rainfall	*15—16*	*5·77*	*8·1*	*18·62*	*26·2*	*46·73*	*65·7*	*71·12*
MALDAH—								
Cholera	23	14	**25·0**	34	**60·7**	8	**14·3**	56
Rainfall	*18—20*	*5·08*	*9·6*	*7·24*	*13·8*	*40·28*	*76·6*	*52·60*
DINAGEPORE—								
Cholera	23	59	**19·9**	185	**62·5**	52	**17·6**	296
Rainfall	*14—16*	*6·17*	*7·8*	*11·65*	*14·8*	*61·09*	*77·4*	*78·91*
PURNEAH—								
Cholera	23	4	**0·6**	598	**95·2**	26	**4·2**	628
Rainfall	*6—7*	*3·93*	*6·4*	*5·44*	*8·9*	*51·84*	*84·7*	*61·21*
MIDNAPORE—								
Cholera	23	20	**3·0**	310	**47·2**	327	**49·8**	657
Rainfall	*11—13*	*6·58*	*11·1*	*9·88*	*16·8*	*42·62*	*72·1*	*59·08*
DINAPORE—								
Cholera	51	426	**12·0**	1,857	**52·3**	1,269	**35·7**	3,552
Rainfall	*17—19*	*2·91*	*7·6*	*3·01*	*7·8*	*32·62*	*84·6*	*38·54*

* If the 113 cases which occurred after the cyclone in August 1859 be deducted, the proportion during the rainy season for Dum-Dum will be 9·1 per cent.; and were a similar deduction made with regard to the 50 cases which occurred at Barrackpore after the same cyclone, the proportion would be 25·1 per cent.

The first column under each seasonal period gives the total number of cholera cases which have been registered in each of the places cited during the months named, and the following column the *proportion* which this number bears to the total number of cases of which records exist as having occurred during the 23 to 51 years that statistics have been collected. The aggregate figures are given in the last column of the table.

The average rainfalls of the seasonal periods have been calculated on the same principle, the proportion to the average of the total annual amount for several years being likewise given in a separate column, and the figures printed in different type for convenience of reference.

If the same mode of calculation be applied to ascertain the prevalence of cholera according to season to the aggregate number registered in all the stations, the cholera of the official and non-official communities of Calcutta being included, we get figures closely approximating to those furnished by Calcutta itself, as the following statement indicates (Table XLVI).

As, however, the Calcutta figures, which include the cholera mortality of the general population, represent nearly ten times the totals of all the other stations, it will be evident that the proportion arrived at might convey a very erroneous impression as to the seasonal prevalence of cholera at the other stations of the table. That such is the case will be seen at a glance from the accompanying statement.

TABLE XLVI.

The prevalence of Cholera according to Seasons in twelve selected Stations in Lower Bengal.

Selected Stations in Endemic Area.	October to December.		January to May.		June to September.		Cholera Grand Total.
	Cholera.		Cholera.		Cholera.		
	Total of season.	Proportion to grand total.	Total of season.	Proportion to grand total.	Total of season.	Proportion to grand total.	
		Per cent.		Per cent.		Per cent.	
Twelve stations including statistics of general Population, Calcutta	31,630	21·2	88,686	59·9	28,220	18·9	148,536
The same stations, but including only the statistics of official communities, Calcutta	2,645	16·9	8,519	54·3	4,535	28·8	15,699

We now find that, whereas the five first months of the year (January to May) furnish 60 per cent. of the total Calcutta cholera and 54 per cent. of the cholera of the endemic area generally, the four months' rainy season (June to September) furnishes 10 per cent. more of the cholera of the selected stations, taken as a group,

than that furnished by Calcutta taken alone. We shall see further on that, as we proceed westwards, this discrepancy becomes greater and greater until areas are reached where the cholera of the rains is not only 10 per cent., but 60, 70, and even more per cent. higher than that of Calcutta.

(d) The Water-level Registers of the Endemic Area.

The water-level returns of the stations forming this group will be found in the alphabetically-arranged tables (I—VII) at pages 302 to 319, together with similar data regarding several other stations situated within the geographical limits under consideration. Unfortunately, an interruption occurred in the observations taken in Lower Bengal during the year 1874, so that, with the exception of Dr. Lynch's observations at the Alipore Jail, the returns for this part of the country are not so satisfactory as those of most other provinces. At several of the stations, however, the fluctuation of the water-level has been recorded with care and for a sufficiently prolonged period to enable a good approximation to be arrived at of the sub-soil changes in adjoining districts. Some of the stations at which the observations have been conducted with special care have no troops, nor have they a jail sufficiently large, or a jail occupied for sufficiently long period, to enable comparisons to be made between the fluctuation of the water-level and the health returns of an accurately registered community. The returns from such stations may, however, prove of much value in future years should the attempts at present being made towards procuring correct statistics from among the general population prove successful.

We have thrown the returns of most of these stations into chart form and have found the result to be so generally alike, that it has not been deemed necessary to reproduce them all. It has been shown that in Calcutta the water-level is at its lowest about May, and nearest the surface in September. Such is also the case in the adjoining military stations of Dum-Dum and Barrackpore; also at Hooghly, Midnapore, Moorshedabad, Burdwan, Purneah, Maldah, Dinapore, and other places.

The period occupied in getting from the lowest to the highest level corresponds consequently with the four months' wet season, and having attained its maximum elevation shortly after the end of the rains, the beginning of its gradual decline may be said to correspond with the commencement of the annual periods into which our seasonal tables have been divided.

CHAPTER II.

ANALYSIS OF DATA FURNISHED BY INDIVIDUAL STATIONS SELECTED TO ILLUSTRATE CHOLERA-PREVALENCE AND PHYSICAL PHENOMENA IN THE ENDEMIC AREA.

(a) Military Stations near Calcutta.

In order to carry out the comparisons between cholera as it occurs in Calcutta and as it occurs in the endemic area generally, we have carefully gone over the

statistical returns of the military stations within short distances of it, and which are, so far as is at present known, identical with it in their physical features. These are Dum-Dum and Barrackpore, situate on the left bank of the Hooghly, and at distances from Calcutta of four and fourteen miles respectively; and one station on the opposite side of the river, about 25 miles from Calcutta—Chinsurah, near Hooghly, where, until recently, a large military depôt was kept up.

Regarding these stations very accurate data are available extending over a period of more than fifty years. In order to ascertain whether any striking agreement exist between the seasonal prevalence of cholera among the civil (as recorded at Calcutta) and purely military population, we have excluded all returns which are in existence in connection with these stations except the strictly military. The following table will show the number of cases which have been furnished by the European and Native troops of these stations—those of Fort William and Alipore being joined and given as the military cholera statistics of Calcutta.

TABLE XLVII.

A Monthly Statement of the Cholera cases that have occurred among the strictly Military population of Calcutta and adjacent Military Stations; also of average Water-level and Rainfall at Chinsurah.

	Number of years returned.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	Remarks.
Calcutta	51	79	127	88	65	109	263	371	297	148	93	84	105	European and Native Troops.
Dum-Dum	25	47	62	23	19	36	65	88	159	67	43	170*	34	,, ,,
Barrackpore	51	274	229	152	84	100	250	318	375	260	137	150	120	,, ,,
Chinsurah (Hooghly)	46	58	63	31	23	50	51	149	166	94	69	74	62	European troops depôt.
Total Cholera	...	458	481	294	191	295	629	926	997	569	342	408*	321	
Mean water-level ...	3	4″·4	5″·4	7″·0	9″·0	10″·1	11″·0	11″·4	11″·8	10″·0	7″·2	3″·0	3″·2	At Chinsurah.
Mean rainfall	12	3‴·94	0‴·41	0‴·15	0‴·61	1‴·48	2‴·18	3‴·68	5‴·23	10‴·65	11‴·97	12‴·31	7‴·88	,,

It will be observed that the data regarding rainfall and water-level are not those of Calcutta, but of the station farthest removed from it, *viz.*, Chinsurah. This has been done with the intention of making the comparison as complete as possible, and likewise because Chinsurah (or rather Hughli) is one of the meteorological

* The cases of cholera which occurred in August 1879, after a cyclone (113 in Dum-Dum and 50 at Barrackpore), have been retained in the table, but these were manifestly exceptional cases, and in order to illustrate the *ordinary* seasonal prevalence of cholera they should be deducted from the total cholera of the four stations. The total would then be [478 − 163 =] 315: this proportion for August has been adopted in the Diagram.

stations from which good water-level returns have been furnished extending over a period of three years.

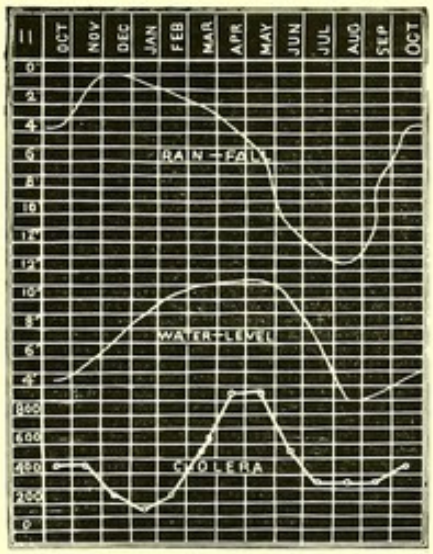


DIAGRAM 11.—Illustrating the average monthly variation in the Water-level at Chinsurah, and the Cholera-prevalence among European and Native troops at Calcutta and adjacent Military Stations.

The above diagram will suffice to illustrate the remarks made in the previous pages regarding the fact that, be the explanation what it may, the prevalence of cholera is at its maximum in Lower Bengal when the water-level is low: not only is this observed in Calcutta itself, nor when judged by data acquired elsewhere from among an indifferently registered civil population, but also when tested by statistics of fairly assured accuracy when they extend over a sufficient number of years.

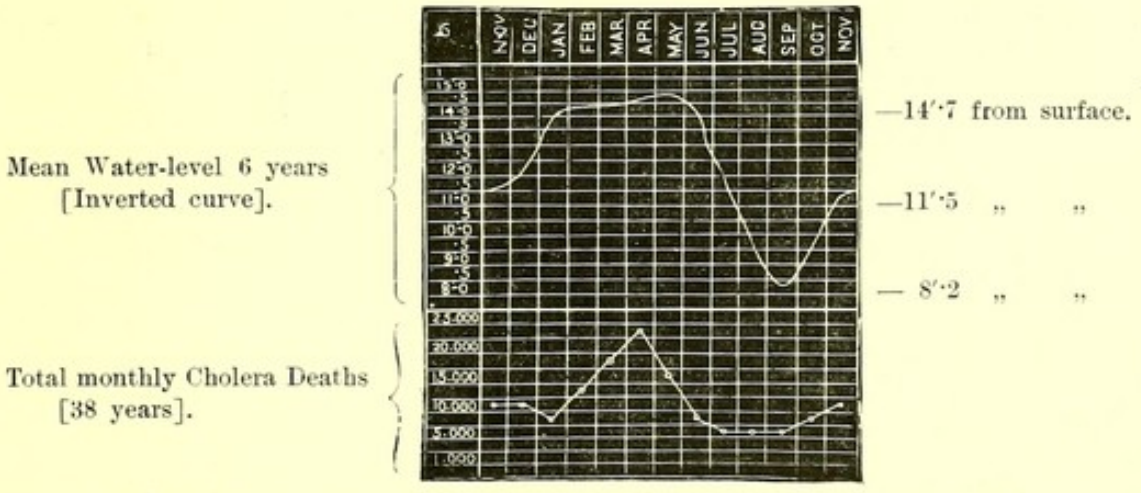


DIAGRAM 11 a.—Average Water-level and Cholera-prevalence in Calcutta.

In order to make this matter more evident, we reproduce the diagram showing the relation which exists between the mean water-level of Calcutta for a period of six years. In both diagrams the water-level is seen to be at its lowest in May and nearest the surface in August and September, and cholera attains its maximum in April and May; as in the

case of Calcutta, however, no close connection can be detected between the less marked variations in the cholera-prevalence and water-level.

As the level of the water in the group of stations under consideration is dependent on the local rainfall, it is not considered necessary to refer to the influence of rainfall specially, as the remarks made regarding this factor in the history of cholera-prevalence when speaking of Calcutta apply equally here. It may, however, be mentioned that in some of these stations, especially at Dum-Dum, it has been ascertained that no relation exists between the height of the river and the level of the water in the well.

(b) The stations of Purneah and Berhampore.

In order to illustrate still further the relation of cholera prevalence to physical conditions in the endemic area, we select three other stations—*Purneah*, *Berhampore* and *Dinapore*. The cholera history of the first two extends over a period of twenty-three years, and regarding the last, records exist extending over more than half a century. The following table gives the monthly prevalence of the disease during the above periods, and also the average monthly rainfall and fluctuation of the water-level:

TABLE XLVIII.

A Monthly Statement of the cases of Cholera that have been registered among Prisoners at Purneah; and among European and Native Troops and Prisoners at Berhampore and Dinapore; also the average Rainfall and Water-level.

	Number of years recorded.	October.	November.	December.	January.	February.	March.	April.	May.	June.	July.	August.	September.	Remarks.
PURNEAH—														
Mean rainfall ...	6—7	3″·81	0″·0	0″·05	0″·40	0″·43	0″·21	1″·84	2″·86	12″·36	14″·90	13″·60	10″·98	
Mean water-level	3—4	2′·2	3′·1	3′·2	4′·0	4′·4	4′·9	5′·1	5′·4	5′·5	4′·4	3′·3	2′·3	
Total cholera ...	23	4	0	0	3	0	220	278	97	22	4	0	0	Prisoners.
BERHAMPORE—														
Mean rainfall ...	18—20	5″·83	0″·17	0″·08	0″·45	0″·92	1″·03	2″·17	3″·99	9″·76	9″·93	9″·91	9″·30	
Mean water-level	2—3	3′·2	4′·2	5′·8	6′·9	7′·7	8′·5	8′·3	10′·6	10′·4	8′·3	5′·2	3′·9	
Total cholera ...	23	89	52	69	42	69	530	263	84	50	90	58	51	European and Native Troops and Prisoners.
DINAPORE—														
Mean rainfall ...	17—19	2″·63	0″·13	0″·15	0″·65	0″·49	0″·25	0″·30	1″·32	6″·87	9″·77	8″·51	7″·47	Patna Observatory.
Mean water-level	1—2	8′·2	15′·7	20′·9	22′·6	24′·1	25′·0	25′·8	26′·2	24′·7	14′·5	8′·9	7′·2	
Total cholera ...	51	137	244	55	46	91	346	672	702	355	403	329	182	European and Native Troops and Prisoners.

The district of Purneah forms a large tract of the alluvial plain lying between the Ganges and the Himalaya, the town itself being about 100 miles to the south of the latter and about 30 from the river. During the greater part of the rainy season the district is more or less completely under water, and, as may be ascertained by reference

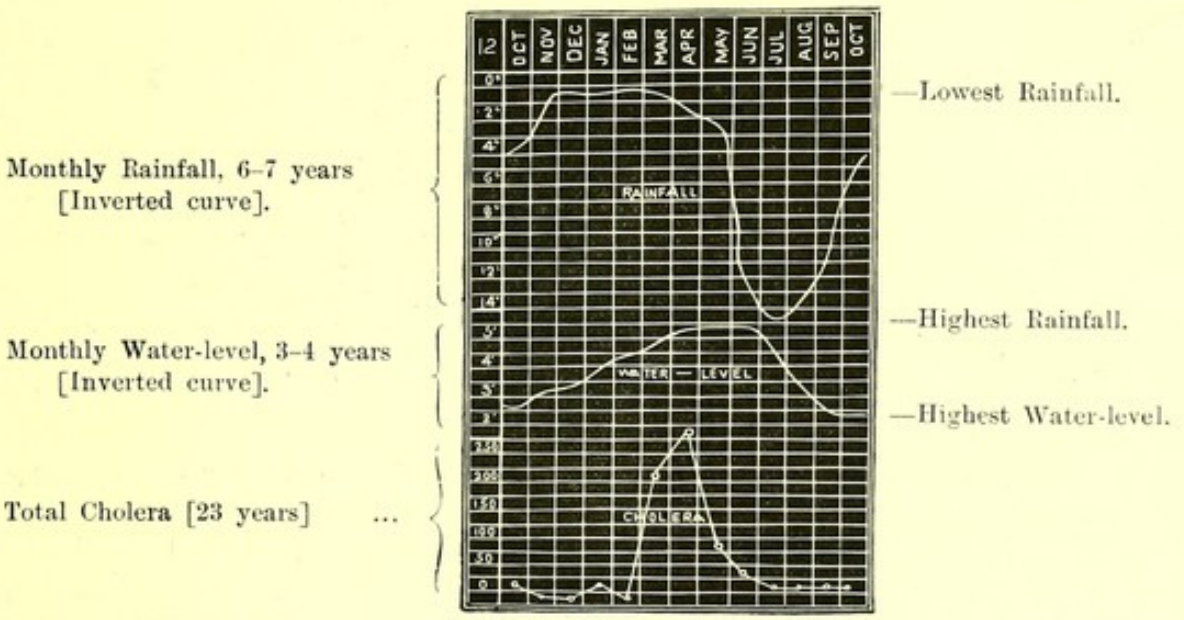


DIAGRAM 12.—Illustrative of the average monthly Rainfall, Water-level, and total monthly Cholera at Purneah.

to the detailed tables of the water-level registers (pages 302 to 319), the water in the station itself may come within a few inches of the surface. Although the total number of carefully registered cases of cholera in the jail is not sufficiently large to justify any opinion as to the minimum cholera month or season, still the preponderance of the disease in April and May is very marked, the cases having occurred in these months on ten different years. With regard to March, the high numbers may be said to be exceptional, as although cases were registered as occurring in this month during six annual periods, 211 out of 220 occurred in March 1863. We have not, however, been able to ascertain the particulars regarding this evidently terrible outburst of the disease among the prisoners at this station.

Berhampore was in former years a large Military station, and over 800 of the cases recorded in the table refer to Europeans. It is within a short distance of the town of Murshidabad, and the statistics of the jail of that station have been incorporated with those of Berhampore.

Here also March and April present a high cholera rate, and this high total rate has not been attained by the occurrence of one exceptionally severe epidemic, but by repeated severe visitations of the disease. In March 1828, and again in 1829, the European troops suffered terribly, as also did the prisoners in March 1856; so that although, according to the summary-tables and diagram, March is the worst month, yet it appears from a study

of the separate annual tables, that it is during April that conditions favouring the disease are most commonly present.

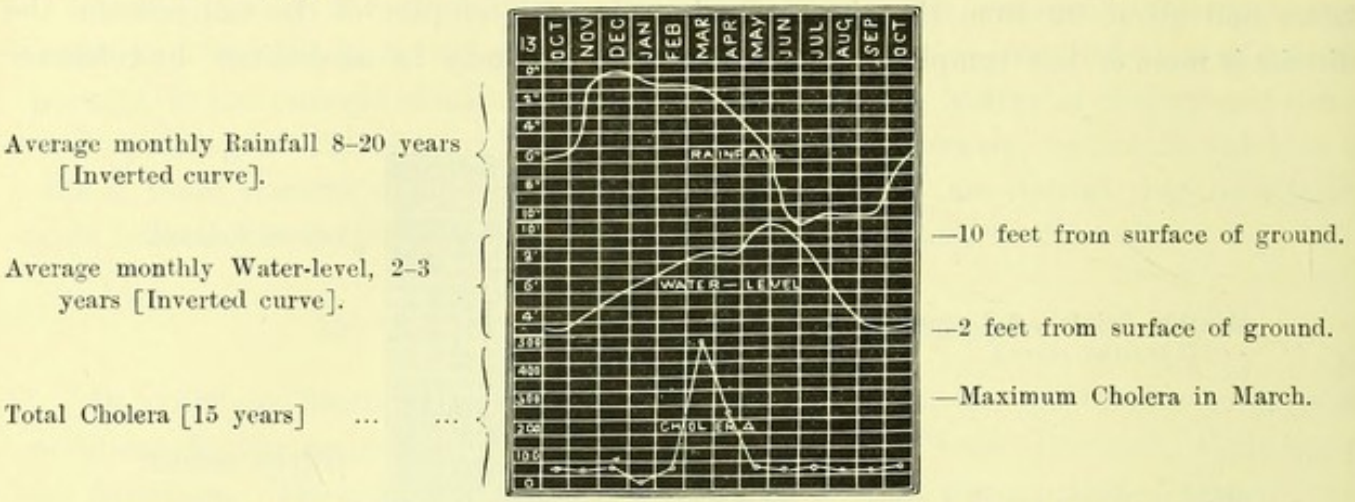


DIAGRAM 13.—Illustrative of the average monthly Rainfall, Water-level, and total monthly Cholera at Berhampore.

(c) Dinapore—a transition area: Geological and Meteorological features.

Dinapore may be said to furnish an illustration of a station in a district forming a sort of border-land between the endemic area and the parts of the country in which experience has shown that cholera is less prone to be constantly present.

It is situated on the south bank of the Ganges, and geologically may be said to present precisely similar conditions to those of the other alluvial stations to which reference has been made.

In a memorandum regarding the sites of Military stations in India, Dr. Oldham, formerly Superintendent of the Geological Survey, states, with reference to this group, that "the conditions of the several stations on the banks of the Ganges are pretty nearly the same, that is, Calcutta, Dum-Dum, Barrackpore, Berhampore, and Dinapore, so far as the geological structure of the ground on which they are placed is concerned, may be said to be similar. They are all built on a series of beds of silt, fine sand and clay of immense thickness, and varying much in the succession. These beds are generally quite or very nearly horizontal, and the character of the surface varies according as the uppermost bed at the place is sand or clay. Not one of these places does or can afford any natural drainage. Soil will, of course, absorb and drink in a large amount of moisture and of impurities also, but there is no means by which these can pass off, and they therefore accumulate. The ground, in fact, licks up moisture and sewage as a sponge would, and as a sponge it also loses these by evaporation, only overflowing when full, but nothing more."

At this part of the country, however, *the character of the alluvium begins to give evidence of a change*—a transition from the more recent Gangetic to the old alluvium (*vide* page 260).

The *rainfall* also undergoes a considerable diminution, for instead of being over 60 inches, as in Calcutta, Purneah, Berhampore and other stations, an average of only

38·5 inches has been recorded during 14 years at a meteorological station about eight miles from Dinapore, the large town of Patna.

Its distribution over the year also is not quite parallel to that of Calcutta, 84·6 per cent. of its annual total falling in the wet season—June to September—against 74·5 per cent. in Calcutta; but even then the aggregate amount of this season's rainfall remains less than that of Calcutta by 16 inches (*vide* Table XLV, page 249).

A comparison of the data regarding Calcutta and Dinapore suggests that conditions of rainfall in a locality (taken in connection with geographical position and geological features) really do exert an important influence on the development and distribution of the cause or causes of cholera. Both stations agree closely in their general physical features, the most important difference lying, as indicated above, in the amount of the rainfall. During the wet season in Dinapore the rainfall is 16 inches less than in Calcutta; this season at Dinapore contributes 35·7 per cent. of the annual cholera, whilst in Calcutta it only gives 18 per cent.

As already stated, however, Dinapore may be looked upon as a transition station, for we shall find the contrast becoming more marked as we proceed in a westerly and north-westerly direction. This important difference cannot be set aside on the ground that the statistics do not comprehend a sufficient number of cases, as may, with perfect justice, be said of some of the endemic-area group of stations which we have been obliged to fall back upon. Here we have a large military station which has been occupied during more than 50 years, and furnishing an aggregate of over 3,500 cases of the disease, among a carefully-registered official population.

This aggregate, moreover, has not been furnished by some *one* extraordinary epidemic, but is distributed over nearly every year of the period: for example, cases have been recorded during 44 years in April, 43 in May, 42 in August, 40 in June, 38 in March, and 34 years in September. It is in January that the disease has occurred least often—21 times.

The data in connection with the hygrometric condition of the atmosphere at this station are not so accurate as those which are available regarding Calcutta, still they are probably sufficiently near to enable a fair estimate of its monthly variation to be formed. We have combined the data furnished in the Bengal Meteorological Report for 1874 with Mr. Blanford's tables for 1875, and thus obtained a monthly mean extending over nine years.

TABLE XLIX.

Mean monthly relative humidity of atmosphere at Dinapore (Patna observations) during nine years; also mean monthly Temperature and atmospheric Pressure.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Relative humidity [Saturation = 100]	9	57	50	58	59	50	37	34	49	63	73	79	76
Temperature	7—8	79°·5	70°·1	62°·7	61°·0	66°·2	77°·5	85°·8	88°·7	87°·6	84°·6	83°·9	83°·3
Atmospheric pressure	7—8	29·675	29·834	29·884	29·858	29·801	29·681	29·568	29·470	29·349	29·359	29·429	29·504

As in Calcutta, the relative humidity of the air at Dinapore bears to a certain extent an inverse relation to the degree of cholera-prevalence; this is brought out very clearly in the diagram (No. 14), where the curve, as in the case of the rainfall and water-level curves, is shown inverted so as to convey a clearer impression of the relation to the cholera and temperature curves forming the lower section of the chart, but which are not reversed.

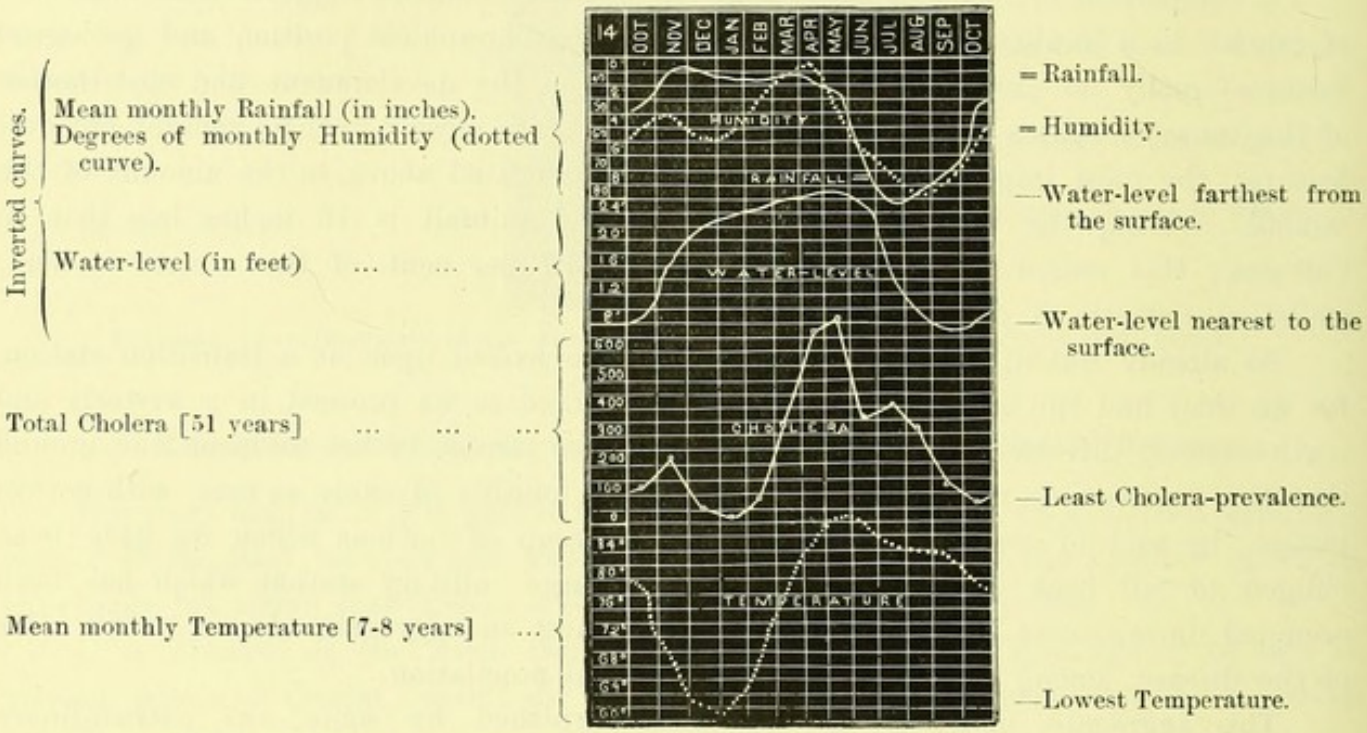


DIAGRAM 14.—Illustrative of average monthly Relative Humidity, Rainfall, Water-level, Temperature, and total Cholera at Dinapore.

The mean monthly *temperature* at Dinapore differs somewhat from that of the stations which are situated further down along the Ganges and its various branches. Taking Calcutta, again, as a standard for comparison, we find that, although the mean temperature of the year does not materially differ, being 79°·3 at Calcutta and 77°·6 at Dinapore, still its distribution over the year presents a marked difference. From April to August the average heat at the latter is greater than at the former by from one to three degrees, but in October the condition becomes reversed, the temperature being from five to six degrees cooler at Dinapore than at Calcutta during the cold season. On comparing the curves in the above diagram, it will be observed that the temperature-curve follows that of the cholera-prevalence curve much more closely than it was observed to do in Calcutta, the *minima* and *maxima* of both at Dinapore corresponding with considerable accuracy. The Calcutta temperature diagram (No. 2) is reproduced here (Diagram 14 a), for convenience of comparison.

No closer relation can be traced between the fluctuation of barometric pressure and the cholera-prevalence at Dinapore than could be done with regard to Calcutta. What correspondence there is, however, is of an inverse kind; for, whereas the periods

of low pressure in Calcutta corresponded generally with those of minimum cholera-prevalence, we find that in the neighbourhood of Dinapore the minimum of pressure corresponds more closely with the maximum of cholera.

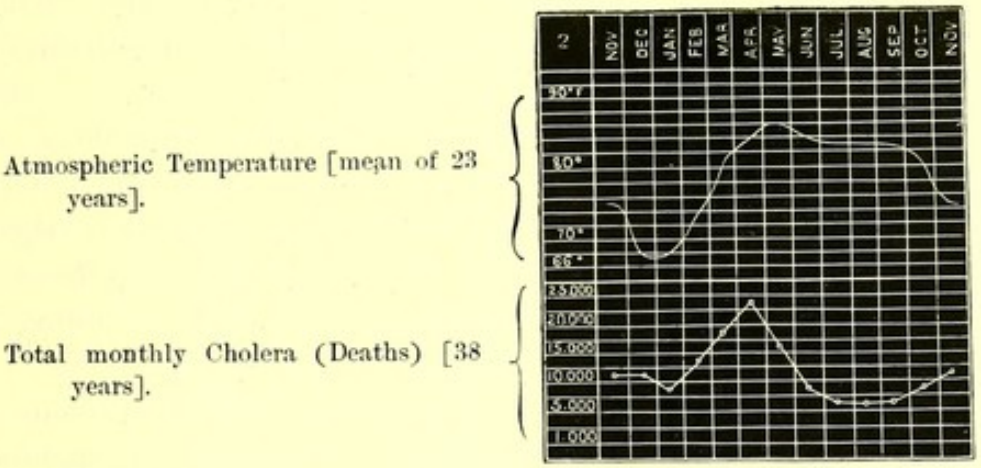


DIAGRAM 14 a.—Atmospheric Temperature and Cholera-Prevalence in Calcutta.

III.—CHOLERA IN THE NON-ENDEMIC AREA OF BENGAL.

CHAPTER I.

THE SEASONAL PREVALENCE OF CHOLERA IN NON-ENDEMIC AREAS OF THE BENGAL PRESIDENCY.

(a) The leading Geological features of the "transition" area, and of the Gangetic plain eastward of 84° East Longitude.

IN the introductory chapter to his work—*Cholera Epidemics of Recent Years*—Dr. Bryden starts with the proposition that the cholera of the Bengal Presidency has a geography which can be demonstrated, that in Upper India the disease has not a permanent habitation, but that in certain areas of the Lower Provinces cholera has a permanent and perennial abode. Other writers also have directed attention to this fact, and it has seemed expedient to epidemiologists to divide the Presidency into two areas—the endemic and the non-endemic.

In the preceding chapters we have endeavoured to point out the leading physical phenomena which are associated with the maximum and minimum prevalence of the disease in the former of the two areas, and we now come to inquire whether a like combination of physical conditions is associated with the maximum and minimum cholera periods in the latter.

The data at our disposal for the study of this matter are derived from similar

communities, and the sources of our information are mainly the same; but we have in addition availed ourselves of the assistance of the compiled statistical details in Dr. J. M. Cuningham's Report on the Cholera Epidemic of 1872.* In the present chapter we have, however, to deal with physical features, geological and climatic, which not only differ in many districts from those observed in the endemic area, but also differ among themselves.

Taking the district of Dinapore as one which presents transitional conditions between the Upper Provinces and Lower Bengal, and between the latter and the Central Provinces, it will perhaps tend to simplify the subject if the physical aspects and cholera-history of those parts of the country which manifest a deviation from the typical cholera-producing area be taken up *seriatim* according to their geographical position.

Reviewing the geological features of the sites upon which the principal military stations above Dinapore have been built, Dr. Oldham, in the memorandum already referred to, states that there are in the Ganges Valley Proper two very distinct deposits of very different ages and probably of very different origin: one being what is described as the old, the other as the Gangetic alluvium (*vide* page 256).

The large city of Benares, some 125 miles higher up the Ganges than Dinapore, may be said to present physical features and a cholera-history closely similar to those of the latter, so that it may be conveniently taken as the starting-point of our description of the leading characters of the physical concomitants of the disease in areas where it appears at irregular intervals. "Below Benares (speaking roughly)," writes Dr. Oldham, "the greater portion of the plain of the Ganges, from the foot of the hills to the north to the hills on the south, is composed of the more recent alluvium, chiefly soft incoherent beds of fine sand and silt, while here and there through these beds stand up parts of the older alluvium (possibly a marine deposit) which for the most part consists of a strongly coherent reddish-yellow clay, generally abounding in *kunkur*,† and with only occasionally irregular beds of sand through it."

It is evident therefore that, speaking *generally*, the soil of the Gangetic plain to the westward of, say, 84° east longitude presents physical properties very different from what we have seen it to present from Dinapore downwards.

Although it is quite true that on looking at a Geological map of India, we find possibly but one tint extending from the mouths of the Ganges to Lahore bounded on the north by the Himalayas and on the other side by an irregular line of elevated country many miles to the south of the course taken by the Ganges and its tributaries, with large patches of the same tint in Central India, signifying that

* Ninth Annual Report of the Sanitary Commissioner with the Government of India—Section 1, 1873.

† *Kunkur* consists of nodular calcareous concretions generally embedded in clay. Mr. W. King states that it derives its origin from decomposed shells and subsequent precipitation of the carbonate of lime derived from them.—*Memoirs of Geological Survey of India*, Vol. IV., page 360.

the territories over which it is spread are alluvial, nevertheless, as Dr. Oldham says, the essential character of the deposit and the physical conditions of the surface vary very materially.

As we have just seen, there is a marked difference between the alluvium found below and above Benares. Speaking generally, the prevailing character of the deposits constituting the plains of Behar and the North-West Provinces consists, not, as below Dinapore, of incoherent sand and silt, but of "layers of older and very kunkury clay." This, says Dr. Oldham, is not universal, but it is general, whereas its absence is the general character below Benares. Moreover, the more superficial deposits present every possible variety, from the barren white saline soil on the one hand to the fertile black cotton soil,* which covers such large tracts, especially of the more southerly portion of the area under review, on the other. It is therefore incorrect to suppose that, taken generally, no material difference exists both as to physical and chemical properties between the soil of the endemic and non-endemic areas.

(b) Prevalence of Cholera according to Monthly periods in the Non-endemic area in Bengal and the mean Monthly Rainfall.

Before proceeding further at present with this subject, it will perhaps be well to adopt the plan followed in Part II., and to take a general inventory of the statistical data at our disposal regarding the particular group of stations now under consideration, previous to entering into details concerning individual stations. In a former chapter, a monthly tabular statement was given of the cholera-prevalence in a dozen stations of the endemic area, together with the average monthly rainfall. We have compiled a similar table (L next page), regarding the cholera and rainfall of 25 selected stations in the non-endemic area of the Bengal Presidency, such stations being selected, as far as possible, which, in addition to furnishing correct returns regarding their military and jail population, were also capable of furnishing meteorological and other collateral data.

* *Regur* or cotton soil has long been a puzzle to Geological and Medical writers. It is generally seen surface-soil covering kunkur and gravelly beds; Captain Newbold (*Journal of the Royal Asiatic Society*, Vol. VIII., p. 254) referring to it writes,—"The best kinds of this extraordinary soil are rarely suffered to lie fallow, and never receive manure. It has yielded annually crop after crop for upwards of 2,000 years without receiving any aid from the hand of man except an annual scratching with a small plough. It is irrigated solely by the dews and rains of heaven. It is remarkably retentive of moisture, and it has been ascertained that if exposed to moist air it will absorb 8 per cent. of its own weight. Contracting by the powerful heat of the sun, it is divided like the surface of dried starch by countless and deep fissures, and while the surface for a few inches in depth is dried to an impalpable powder raised in clouds by the wind, darkening the air, the lower portion of the deposit still retains the character of hard black clay. In wet weather the surface is converted into a deep tenacious mud."

Mr. W. T. Blanford says that it is extremely adhesive when wetted, and expands and contracts to an unusual extent under the respective influences of moisture and dryness, hence the great cracks by which it is fissured in hot weather. Like all argillaceous soils it retains water, and hence requires less irrigation than more sandy ground.—*Memoirs of the Geological Survey of India*, Vol. VI., p. 235.

TABLE I.

A Monthly Statement of Cholera in the principal Stations of the Non-Endemic Area among European and Native Troops and Prisoners for periods of 18 *to* 51 *years, together with the average Monthly Rainfall.*

Stations.	Elevation in feet.	Number of years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Remarks.
HAZAREEBAUGH	2,010															
Cholera ...	...	23	1	1	33	60	61	45	201	80	22	2	3	0	509	Soldiers and prisoners.
Rainfall ...	...	*10—11*	*0·47*	*0·81*	*0·63*	*0·40*	*1·33*	*8·52*	*14·15*	*13·30*	*8·25*	*3·42*	*0·19*	*0·06*	*51·53*	
RANCHEE ...	...															
Cholera ...	...	23	1	1	5	12	16	20	63	43	3	0	2	0	166	
Rainfall ...	...	*16—18*	*0·92*	*1·04*	*1·31*	*0·58*	*1·52*	*7·43*	*12·50*	*10·90*	*7·81*	*3·45*	*0·13*	*0·09*	*47·68*	
ARRAH	191															
Cholera ...	...	23	0	2	8	21	15	92	229	60	8	9	20	0	464	Prisoners.
Rainfall ...	...	*17—19*	*0·84*	*0·45*	*0·59*	*0·76*	*1·06*	*7·10*	*12·91*	*10·04*	*9·65*	*2·60*	*0·21*	*0·07*	*46·28*	
BENARES	267															
Cholera ...	...	51	31	26	139	245	216	188	187	380	77	52	29	40	1,610	Soldiers, sepoys, and prisoners.
Rainfall ...	...	*20—21*	*0·70*	*0·47*	*0·26*	*0·15*	*0·48*	*5·26*	*12·67*	*11·88*	*6·86*	*1·63*	*0·05*	*0·08*	*40·49*	
GORUCKPORE ...	255															
Cholera ...	...	23	0	1	12	10	22	32	249	35	28	5	18	1	413	Prisoners.
Rainfall ...	...	*20*	*0·49*	*0·55*	*0·33*	*0·26*	*1·59*	*6·57*	*13·46*	*11·88*	*8·19*	*2·77*	*0·24*	*0·09*	*46·42*	
FYZABAD ...	400?															
Cholera ...	...	18	1	3	4	133	13	6	6	62	69	71	16	1	385	Soldiers, sepoys, and prisoners.
Rainfall ...	...	*5—6*	*0·20*	*0·20*	*0·10*	*0*	*0*	*8·70*	*13·90*	*14·30*	*8·60*	*2·50*	*2·10*	*2·30*	*52·90*	
ALLAHABAD ...	306															
Cholera ...	...	50	8	14	105	128	310	213	192	417	146	20	14	5	1,572	Ditto ditto.
Rainfall ...	...	*19—20*	*0·75*	*0·57*	*0·23*	*0·18*	*0·38*	*3·43*	*12·04*	*10·67*	*6·62*	*2·47*	*0·09*	*0·15*	*37·58*	
LUCKNOW ...	369															
Cholera ...	...	21	1	4	44	63	43	74	329	321	179	58	111	7	1,234	Ditto ditto.
Rainfall ...	...	*11*	*0·99*	*0·16*	*0·25*	*0·19*	*0·56*	*4·66*	*14·10*	*10·93*	*9·90*	*1·27*	*0*	*0·34*	*43·35*	
CAWNPORE ...	113															
Cholera ...	...	51	42	39	203	287	424	653	834	1,246	441	111	82	75	4,437	Ditto ditto.
Rainfall ...	...	*20*	*0·66*	*0·48*	*0·24*	*0·09*	*0·56*	*3·38*	*9·24*	*7·80*	*5·40*	*0·80*	*0·09*	*0·15*	*28·89*	
AGRA	555															
Cholera ...	...	51	1	13	70	117	150	832	683	1,391	133	50	32	19	3,501	Ditto ditto.
Rainfall ...	...	*22—25*	*0·71*	*0·42*	*0·24*	*0·13*	*0·63*	*2·89*	*8·86*	*7·24*	*4·88*	*0·22*	*0·03*	*0·16*	*26·41*	
MUTTRA	550?															
Cholera ...	..	51	0	2	3	25	1	6	14	94	6	1	4	1	157	Ditto ditto.
Rainfall ...	...	*19*	*0·49*	*0·42*	*0·25*	*0·11*	*0·69*	*2·78*	*9·56*	*7·45*	*4·76*	*0·19*	*0·01*	*0·30*	*27·01*	
MORAR	500?															
Cholera ...	...	17	1	0	1	41	20	12	108	438	91	11	2	1	726	Ditto ditto.
Rainfall ...	...	*9—12*	*1·26*	*0·27*	*0·25*	*0·03*	*0·31*	*3·88*	*12·40*	*9·62*	*5·13*	*1·04*	*0*	*0·21*	*34·40*	
JHANSIE	359															
Cholera ...	...	22	0	0	0	0	0	2	21	134	8	0	0	1	166	
Rainfall ...	...	*9—12*	*1·26*	*0·27*	*0·25*	*0·03*	*0·31*	*3·88*	*12·40*	*9·62*	*5·13*	*1·04*	*0*	*0·21*	*34·40*	

TABLE L.—*continued.*

A Monthly Statement of Cholera in the principal Stations of the Non-Endemic Area among European and Native Troops and Prisoners for periods of 18 *to* 51 *years, together with the average Monthly Rainfall.*

Stations.	Elevation in feet.	Number of years.	January.	February.	March.	April.	May.	June.	July.	August.	September.	October.	November.	December.	Total.	Remarks.
SAUGOR	1,766															
Cholera ...	...	23	0	1	1	2	30	11	57	78	33	39	0	0	252	Soldiers, sepoys, and prisoners.
Rainfall ...	...	*19—20*	*0·61*	*0·68*	*0·14*	*0·20*	*0·55*	*6·23*	*18·26*	*12·03*	*8·51*	*1·01*	*0·31*	*0·27*	*48·80*	
JUBBULPORE ...	1,351															
Cholera ...	...	21	0	1	3	9	46	68	340	196	13	12	1	1	690	Ditto ditto.
Rainfall ...	...	*32—33*	*0·60*	*0·47*	*0·46*	*0·13*	*0·35*	*7·66*	*18·41*	*14·12*	*8·53*	*1·33*	*0·30*	*0·19*	*52·55*	
RAIPORE... ...	960															
Cholera ...	...	22	0	0	6	11	48	52	136	31	0	1	0	0	285	Prisoners.
Rainfall ...	...	*12—14*	*0·26*	*0·23*	*0·49*	*0·48*	*0·57*	*9·22*	*14·49*	*12·21*	*8·05*	*1·76*	*0·90*	*0·10*	*48·76*	
DELHI	717															
Cholera ...	...	32	0	2	8	16	9	56	309	99	137	22	8	5	671	Soldiers, sepoys, and prisoners.
Rainfall ...	...	*17*	*0·99*	*0·51*	*0·83*	*0·29*	*0·86*	*3·01*	*7·41*	*5·42*	*4·41*	*0·31*	*0·07*	*0·30*	*24·41*	
MEERUT	739															
Cholera ...	...	51	19	16	60	132	126	161	407	1,055	450	66	68	36	2,596	Ditto ditto.
Rainfall ...	...	*20*	*0·72*	*0·84*	*0·56*	*0·39*	*0·93*	*3·78*	*9·70*	*6·71*	*4·01*	*0·22*	*0·02*	*0·21*	*28·09*	
UMBALLA ...	902															
Cholera ...	...	34	1	4	9	42	115	49	167	439	303	47	24	5	1,205	Ditto ditto.
Rainfall ...	...	*10*	*0·54*	*1·26*	*1·13*	*0·79*	*1·04*	*4·46*	*12·76*	*7·90*	*5·28*	*0·30*	*0*	*0·32*	*35·78*	
LAHORE	739															
Cholera ...	...	31	1	1	3	15	3	12	24	491	235	4	2	2	793	Ditto ditto.
Rainfall ...	...	*10*	*0·50*	*0·91*	*0·91*	*0·27*	*0·92*	*1·20*	*6·29*	*3·89*	*2·54*	*0·60*	*0*	*0·50*	*18·53*	
MEEAN MEER ...	...															
Cholera ...	...	25	2	0	1	2	13	14	76	1,489	238	8	1	1	1,845	Soldiers and sepoys.
Rainfall ...	...	*10*	*0·50*	*0·91*	*0·91*	*0·27*	*0·92*	*1·20*	*6·29*	*3·89*	*2·54*	*0·50*	*0*	*0·50*	*18·53*	
SEALKOTE ...	829															
Cholera ...	...	24	0	0	0	3	5	2	2	44	23	0	0	1	80	Soldiers, sepoys, and prisoners.
Rainfall ...	...	*9*	*1·10*	*1·70*	*2·30*	*1·30*	*1·10*	*2·80*	*12·30*	*10·60*	*4·00*	*0·30*	*0*	*0·40*	*37·90*	
MOOLTAN ...	420															
Cholera ...	...	25	0	1	1	1	1	1	4	7	1	5	3	0	25	Soldiers and sepoys.
Rainfall ...	...	*9*	*0·3*	*0·1*	*0·7*	*0·5*	*0·4*	*0·1*	*2·2*	*1·1*	*0·4*	*0*	*0*	*0·3*	*6·1*	
RAWUL PINDEE	1,650															
Cholera ...	...	28	1	0	0	2	10	13	9	21	10	5	4	1	76	Ditto ditto.
Rainfall ...	...	*10*	*2·05*	*1·81*	*2·75*	*1·63*	*1·18*	*1·99*	*8·28*	*6·15*	*3·73*	*0·64*	*0·33*	*1·00*	*31·54*	
PESHAWUR ...	1,165															
Cholera ...	...	28	3	0	1	5	205	164	131	25	577	343	26	0	1,480	Ditto ditto.
Rainfall ...	...	*10*	*1·32*	*1·26*	*1·60*	*1·25*	*0·60*	*0·21*	*1·75*	*2·64*	*1·06*	*0·36*	*0·31*	*0·55*	*12·91*	

Now, on comparing this table with the one [Table XLIII, page 246] regarding the monthly prevalence of cholera in the endemic area, attention is at once arrested by the circumstance that the months of maximum prevalence in the two groups of stations do not coincide—July, August and September being the months of maximum in the group of stations which forms the subject of the present chapter, whereas, so far as the cholera-history of Calcutta itself goes, they are the most favourable, and even when the endemic-area stations are taken as a group furnish a minor proportion of the total.

Twenty-five stations have been selected in the different districts of Upper and Central India, and, with a single exception, July or August has furnished the largest number of the registered cases of cholera in every one of them. The exception is Peshawur, which has its maximum of cholera in September. This station will be referred to further on.

It will be recollected that the dozen stations which we selected for illustrating the seasonal prevalence of the disease in the endemic area furnished 15,699 registered cases of cholera from among the official communities, regarding whom alone, as already explained, it is possible at present to obtain satisfactory statistics. The cholera returns collected from among 25 similar groups of the population in stations situated beyond the bounds of the endemic area amount to 25,338. The aggregate monthly cholera statistics of the selected group of stations in the endemic area were given at page 248 (Table XLIV), and a similar summary regarding the other group is annexed :

TABLE LI.

The aggregate monthly prevalence of Cholera among Soldiers, Sepoys and Prisoners at 25 Stations in Upper and Central India during periods of from 18 *to* 51 *years.*

	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.	Total.
Cholera ...	942	470	203	124	132	720	1,382	1,902	2,778	4,778	8,676	3,231	25,338

A comparison of the above summarised statement with the like summary regarding the endemic group of stations, omitting Calcutta, presents some points of resemblance as well as of contrast. In both tables January is seen to occupy the lowest place as to cholera-prevalence, and in both also there is shown that a gradual increase of the disease takes place with the progress of the year. In Lower Bengal, however, the maximum culminates in April and declines month by month till September, when a slight rise occurs until November, and it then subsides till minimum is reached; but in the non-endemic provinces, instead of a remission of the disease

taking place in June and the subsequent months, there is unmistakable evidence of its increase, and this continues until the maximum is reached in August—this month furnishing almost twice as many cases as its predecessor and nearly three times as many as September; there is, therefore, overwhelming evidence to show that, be the actual conditions favourable to the manifestation of the disease what they may, they are present to a far greater extent during the month of August in the non-endemic area generally than at any other period of the year. The study of the *proportion* between the cholera-prevalence of the two areas, when compared month by month, will be simplified by a scrutiny of the accompanying table in which the percentages have been calculated.

TABLE LII.

The Monthly Proportion of Cholera-prevalence to total Cholera in the selected groups of Stations of the Endemic and Non-endemic Areas.

	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Total cholera from which the percentage has been calculated.
	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	Per cent.	
ENDEMIC AREA—													
Calcutta	5·9	8·2	7·6	6·7	9·3	14·4	17·7	12·2	6·3	3·9	3·8	4·0	135,833
Group of 12 stations ...	6·4	6·6	3·9	2·7	4·5	15·0	18·1	14·0	9·8	7·3	6·5	5·2	15,699
NON-ENDEMIC AREA—													
Group of 25 stations ...	3·7	1·8	0·8	0·5	0·5	3·8	5·5	7·5	10·0	18·9	34·2	12·8	25,338

The fact that whereas, taking the whole group of stations in the non-endemic area, 34·2 per cent. of their total cholera occurs in the month of August, only 6·5 per cent. occurs in the group illustrative of the endemic area, and still less, 3·8 per cent., in Calcutta when taken by itself during the same month, cannot but arrest the attention of the student.

(c) Prevalence of Cholera according to Seasons in the Non-endemic Area, and the Mean Rainfall for the same Seasons.

If the principle adopted in a previous chapter of classifying the disease into seasons comparable with the three seasons into which each annual period naturally falls in India be applied to the group of stations in the non-endemic area also, we shall see that the cholera-prevalence in the two areas presents still greater contrasts than was manifested in the classification by months. The following table (LIII), which has been prepared in the same manner as Table XLV (page 249), will enable students to ascertain at a glance what these salient contrasts are. The rainfall has likewise been given here, and the average proportion for each seasonal period calculated out.

TABLE LIII.

The prevalence of Cholera according to Seasons, together with the seasonal Rainfall at 25 Stations in Central and Upper India.

STATIONS.	Number of years.	October to December.		January to May.		June to September.		Totals of cholera and annual rainfall.
		Cholera and rainfall (3 months).	Percentage to annual totals.	Cholera and rainfall (5 months).	Percentage to annual totals.	Cholera and rainfall (4 months).	Percentage to annual totals.	
HAZARIBAUGH—								
Cholera	23	5	1·0	156	30·7	348	68·3	509
Rainfall	*10—11*	*3·67*	*7·1*	*3·64*	*7·1*	*44·22*	*85·8*	*51·53*
RANCHEE—								
Cholera	23	2	1·2	35	21·1	129	77·7	166
Rainfall	*16—18*	*3·67*	*7·7*	*5·37*	*11·3*	*38·64*	*81·0*	*47·68*
ARRAH—								
Cholera	23	29	6·3	4·6	9·9	389	83·8	464
Rainfall	*17—19*	*2·88*	*6·3*	*3·70*	*7·9*	*39·70*	*85·8*	*46·28*
BENARES—								
Cholera	51	121	7·5	657	40·8	832	51·7	1,610
Rainfall	*20—21*	*1·76*	*4·4*	*2·06*	*5·0*	*36·67*	*90·6*	*40·49*
GORUCKPORE—								
Cholera	23	24	5·8	45	10·9	344	83·3	413
Rainfall	*20*	*3·10*	*·6·7*	*3·22*	*6·9*	*40·10*	*86·4*	*46·42*
FYZABAD—								
Cholera	18	88	22·9	154	40·0	143	37·1	385
Rainfall	*5—6*	*6·9*	*13·1*	*0·5*	*0·9*	*45·5*	*86·0*	*52·90*
ALLAHABAD—								
Cholera	50	39	2·5	565	35·9	968	61·6	1,572
Rainfall	*19—20*	*2·71*	*7·2*	*2·11*	*5·6*	*32·76*	*87·2*	*37·58*
LUCKNOW—								
Cholera	21	176	14·3	155	12·5	903	73·2	1,234
Rainfall	*11*	*1·61*	*3·7*	*2·15*	*4·9*	*39·59*	*91·4*	*43·35*
CAWNPORE—								
Cholera	51	268	6·1	995	22·4	3,174	71·5	4,437
Rainfall	*20*	*1·04*	*3·6*	*2·03*	*7·0*	*25·82*	*89·4*	*28·89*
AGRA—								
Cholera	51	101	2·9	361	10·3	3,039	86·8	3,501
Rainfall	*22—25*	*0·41*	*1·5*	*2·13*	*8·1*	*23·87*	*90·4*	*26·41*
MUTTRA—								
Cholera	51	6	3·8	31	19·8	120	76·4	157
Rainfall	*19*	*0·50*	*1·8*	*1·96*	*7·3*	*24·55*	*90·9*	*27·01*
MORAR—								
Cholera	17	14	1·9	63	8·7	649	89·4	726
Rainfall *	*9—12*	*1·25*	*3·6*	*2·12*	*6·2*	*31·03*	*90·2*	*34·40*
JHANSIE—								
Cholera	22	1	0·6	.....	.....	165	99·4	166
Rainfall	*9—12*	*1·25*	*3·6*	*2·12*	*6·2*	*31·03*	*90·2*	*34·40*
SAUGOR—								
Cholera	23	39	15·5	34	13·5	179	71·0	252
Rainfall	*19—20*	*1·59*	*3·2*	*2·18*	*4·5*	*45·03*	*92·3*	*48·80*
JUBBULPORE—								
Cholera	21	14	2·0	59	8·6	617	89·4	690
Rainfall	*32—33*	*1·82*	*3·5*	*2·01*	*3·8*	*48·72*	*92·7*	*52·55*
RAIPUR—								
Cholera	22	1	0·3	65	22·8	219	76·9	285
Rainfall	*12—14*	*2·76*	*5·6*	*2·03*	*4·2*	*43·97*	*90·2*	*48·76*

* Jhansie rainfall returns.

TABLE LIII.—(*continued.*)

The prevalence of Cholera according to Seasons, together with the seasonal Rainfall at 25 Stations in Central and Upper India.

STATIONS.	Number of years.	OCTOBER TO DECEMBER.		JANUARY TO MAY.		JUNE TO SEPTEMBER.		Totals of cholera and annual rainfall.
		Cholera and rainfall (3 months).	Percentage to annual totals.	Cholera and rainfall (5 months).	Percentage to annual totals.	Cholera and rainfall (4 months).	Percentage to annual totals.	
DELHI—								
Cholera	32	35	**5·2**	35	**5·2**	601	**89·6**	671
Rainfall	*17*	*0·68*	*2·8*	*3·48*	*14·3*	*20·25*	*82·9*	*24·41*
MEERUT—								
Cholera	51	170	**6·5**	353	**13·6**	2,073	**79·9**	2,596
Rainfall	*20*	*0·45*	*1·6*	*3·44*	*12·2*	*24·20*	*86·2*	*28·90*
UMBALLAH—								
Cholera	34	76	**6·3**	171	**14·2**	**958**	**79·5**	1,205
Rainfall	*10*	*0·62*	*1·8*	*4·76*	*13·3*	*30·40*	*84·9*	*35·78*
LAHORE—								
Cholera	31	8	**1·0**	23	**·29**	762	**96·1**	793
Rainfall	*10*	*1·10*	*5·9*	*3·51*	*18·9*	*13·92*	*75·2*	*18·53*
MEEAN MEER—								
Cholera	25	10	**0·6**	18	**1·0**	1,817	**98·4**	1,845
Rainfall	*10*	*1·10*	*5·9*	*3·51*	*18·9*	*13·92*	*75·2*	*18·53*
SEALKOTE—								
Cholera	24	1	**1·2**	8	**10·0**	71	**88·8**	80
Rainfall	*9*	*0·70*	*1·8*	*7·50*	*19·8*	*29·70*	*78·4*	*37·90*
MOOLTAN—								
Cholera	25	8	**32·0**	4	**16·0**	13	**52·0**	25
Rainfall	*9*	*0·30*	*4·9*	*2·00*	*32·8*	*3·80*	*62·3*	*6·10*
RAWUL PINDEE—								
Cholera	28	10	**13·2**	13	**17·1**	53	**69·7**	76
Rainfall	*10*	*1·97*	*6·2*	*9·42*	*29·9*	*20·15*	*63·9*	*31·54*
PESHAWUR—								
Cholera	28	369	**24·9**	214	**14·5**	897	**60·6**	1,480
Rainfall	*10*	*1·22*	.....	*6·03*	*46·7*	*5·66*	*43·8*	*12·91*

In comparing the two tables, it will be remarked that in the endemic area the first five months of the year furnish in most places more than half of the whole year's cholera—in some of them very considerably more—the average contribution of the stations, including Calcutta, being 59·9 per cent., or excluding the statistics of the general population of Calcutta, 54·3. The aggregate cholera of the same season—the "spring cholera"—in the non-endemic group of stations, yields, however, a very different proportion, *viz.*, 16·8 per cent. of the total of the yearly period. Further, if the cholera of the rainy period be compared with the cholera of the rest of the year, we find that whereas in the endemic area the rainy season furnishes only 28·8 per cent. and the dry season (October to May) 71·2 per cent. of the total annual cholera, in the non-endemic area the same seasons respectively furnish 76·8 and 23·2 per cent. These facts will become more evident when arranged in tabular form.

TABLE LIV.

A Summary of a portion of Tables XLV. and LIII. giving the percentages of the aggregate seasonal Cholera in the selected group of Stations of the Endemic and Non-endemic areas.

Area.	October to December.		January to May.		October to May.	June to September (rainy season).		
	Total cholera of group of stations (3 months).	Percentage to total for the whole annual period.	Total cholera of group of stations (5 months).	Percentage to total for the whole annual period.	Percentage of cholera for 8 months to whole annual period.	Total cholera of group of stations (4 months).	Percentage to total for the whole annual period.	The total cholera of group.
Endemic Area—								
Calcutta (general population)...	29,462	21·7	81,916	60·3	82·0	24,445	18·0	135,833
12 stations (troops and prisoners)	2,645	16·9	8,519	54·3	71·2	4,535	28·8	15,699
Non-endemic area—								
25 stations (troops and prisoners)	1,615	6·4	4,260	16·8	23·2	19,463	76·8	25,338

Although the impression conveyed by a scrutiny of these tables regarding the seasonal prevalence of cholera in the non-endemic area is clear enough taking the stations as a group, it will nevertheless be observed that there are some half-dozen out of the 25 stations where cholera appears to be more equally distributed over the several seasons, approximating more closely to what is observed in Lower Bengal, as, for example, instead of furnishing a proportion of "spring" cholera of about the average, *viz.*, 16·8 per cent., they furnish from 20 to 40—a proportion which, though considerably less than that of the Lower Bengal stations, approximates sufficiently near to command attention. It will, however, be more convenient to consider this question when the cholera-history and physical phenomena of individual stations come under review.

It will be more convenient also to defer the study of the relation which the average monthly and seasonal rainfall may hold to cholera-prevalence. It will be sufficient to observe here that the proportion of rain which falls over the two great areas into which epidemiologists have divided the province of Bengal, not only differs as to amount, but also as to its proportionate distribution over the annual period. For example, if the mean of the rainfall of the wet season—June to September—at the several stations which form our Lower Bengal group, be calculated, it will be found that it is equal to about 75 per cent. of the total fall for the year; but the mean of the rainfall of the selected group of stations in the non-endemic area for the same period exceeds this by 10 per cent.; hence during the winter and "spring" seasons, the rainfall of the non-endemic area is not only less because the total annual fall is less, but also because proportionately so much more of it falls during the wet season. There are, as might have been anticipated, some deviations from these results in individual stations in

both groups, but taken as representatives of two large tracts of territory, the figures are highly suggestive.

TABLE LV.

A Summary of a portion of Tables XLV and LIII giving the percentage of seasonal rainfall to annual rainfall in the selected group of Stations of the Endemic and Non-endemic areas.

Area.	October to December.		January to May.		October to May.	June to September.		
	Average total rainfall of group of stations(3 months).	Percentage to total of average annual rainfall.	Average total rainfall of group of stations(5 months).	Percentage to total of average annual rainfall.	Percentage to total average annual rainfall of group of stations.	Average total rainfall of group of stations(4 months).	Percentage to total average annual rainfall.	Total average annual rainfall of group of stations.
Endemic Area— 12 stations	5″·6	9·1	9″·9	16·3	25·4	45″·6	74·6	61″·1
Non-endemic Area— 25 stations	1″·8	5·1	3″·3	9·4	14·5	30″·1	85·5	35·2

A summary of the water-level registers which have reached us from the stations situated in the non-endemic area at present under review will be found in the first set of tables, arranged alphabetically (pages 302 to 319). It will be more instructive to consider the possible relation which soil-moisture may bear to cholera-prevalence in connection with the description of the separate stations where the observations were conducted. It will be observed that many of the wells selected for the purpose of registering the fluctuation of the water in them are very deep—far too deep, indeed, to be of material aid in estimating the degree of moisture of the more superficial strata. This was unavoidable in most instances, as no permanent water-supply was attainable nearer to the surface. In such cases we have, in the following illustrative stations, taken the mean rainfall as a more certain index of the hygroscopic condition of the soil. The highest point of the water-level registered in the course of the series has, however, been noted, but when this does not reach to within about 20 feet of the surface, it has not been considered necessary to refer specially to the monthly range.

CHAPTER II.

ANALYSIS OF DATA FURNISHED BY INDIVIDUAL STATIONS SELECTED TO ILLUSTRATE CHOLERA-PREVALENCE AND PHYSICAL PHENOMENA IN NON-ENDEMIC AREAS.

(a) Selected Stations—Oudh and the North-Western Provinces.

FOLLOWING the plan adopted when referring to the endemic area, we now propose to subdivide the group of stations which have been described collectively in the previous chapter, and which may be said to represent in a general way the physical conditions and predisposition to the occurrence of cholera of those portions of Upper and Central India which have been defined as constituting the non-endemic area of the Presidency.

Owing, however, to the very varied character of the provinces in which the selected stations are located, and to their differences in telluric conditions and climate, especially as regards rainfall and range of temperature, it becomes a matter of some difficulty to classify them satisfactorily. On this account it seems best to take them according to their geographical position, proceeding in a north and south-westerly direction from Dinapore.

(1) BENARES.

The first large station of importance is the City of Benares. This can scarcely be said to be beyond the borders of the endemic area, and its monthly cholera chart for the last 51 years would of itself be sufficient almost to imply as much; indeed the disease is seldom absent either from the city or the district. In the previous chapter it was shown that cholera, instead of being diffused so generally over the year as in the endemic area and reaching its maximum in March or April, flourished far more during August and the rainy season generally in the non-endemic area. At this station this peculiarity is not very marked; though it is true that considerably more cholera has occurred in August than in April, still the history of the cholera of the latter month proves that the conditions which prevail during March, April and May in the more strictly endemic area are also influential during the same periods at Benares.

TABLE LVI.

The average Monthly Rainfall, Relative Humidity, Temperature, Atmospheric Pressure, and the total Cholera among European and Native troops and prisoners at Benares.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.,	Sept.
Water-level	...	Highest registered level of selected well = 28 feet.											
Rainfall [in inches]	20—21	1″·63	3″·05	0″·08	0″·70	0″·47	0″·26	0″·15	0″·48	5″·26	12″·67	11″·88	6″·86
Humidity [Sat. = 100]	7	51	47	50	51	41	29	26	28	52	74	74	72
Temperature [° Fahr.]	7—9	78°·8	68°·8	60°·5	59°·3	67°·0	76°·4	86°·8	91°·8	90°·4	85°·4	84°·5	83°·9
Atmospheric pressure	7—8	29·59	29·74	29·79	29·77	29·71	29·61	29·48	29·38	29·64	29·71	29·33	29·42
Cholera	51	52	29	40	31	26	139	245	216	188	187	380	77

This station gets 28 inches less *rain* than Calcutta, and 20 less than the average of the group of the endemic area stations; but it gets more than Dinapore, although the latter is farther down the Ganges. The months of lowest *temperature* are also the months of minimum cholera; and although the months of mean maximum temperature do not coincide with the maximum cholera-months, there is yet a certain degree of coincidence between the degree of temperature and cholera prevalence. The mere fact of a month being warm, however, by no means implies a corresponding increase of cholera; on the contrary the tables show that, whereas 380 cases have occurred during 51 years in August, only 77 occurred in September, although the mean temperature of the latter month is only half a degree lower than the former. The temperature becomes 2° cooler in January than at Dinapore, but on the other hand is a couple of degrees warmer at the maximum in May.

One of the months of maximum relative *humidity* (August) coincides with the maximum cholera, but the month preceding this has the same mean hygrometric condition with only half the cholera, and the month after it is nearly equally moist and warm, but has only a fifth of the cholera: on the other hand, the driest month of the year (April) furnishes the next highest number of cholera cases.

With regard to the state of the barometer, it will be seen that the highest *pressure* corresponds for the most part with months of minimum cholera, and it so happens that the lowest pressure corresponds with the maximum—the reverse of the general result of the Calcutta analysis,—where the minimum cholera (July and August) and minimum average pressure almost coincided.

(2) Allahabad.

Following the course of the Ganges, the next important station of which we possess fair data is the City of Allahabad, situated at the angle formed by the junction of the Jumna and the Ganges. We have now followed the latter from Calcutta, a distance of some 600 miles, and observed the gradual transition of the maximum of cholera-prevalence at the several stations of its plains from March and April to July and August.

This station, however, still manifests, to a considerable extent, the tendency to suffer from cholera during the spring season, as nearly 36 per cent. of its total cholera has occurred during the first five months of the year, January to May, the three months March to May furnishing nearly the whole of them.

On the other hand, the last three months of the year, October to December, furnish very few, only 2 per cent. of the total, or about 14 per cent. less than the proportion furnished by the group of stations in the endemic area; while during the rainy season nearly 33 per cent. more occur, so that the contrast is very considerable.

TABLE LVII.

The average Monthly Rainfall, Relative Humidity, Temperature, and the total Cholera among the European and native troops and prisoners at Allahabad.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Water-level				Highest registered level in selected well 48 feet.									
Rainfall [in inches]... ...	19—20	2″·47	0″·09	0″·15	0″·75	0″·57	0″·23	0″·18	0″·38	3″·43	12″·04	10″·67	6″·62
Humidity [Sat. = 100] ...	3—6	54	46	55	50	51	35	26	35	55	77	83	77
Temperature [° Fahr.] ...	6—7	77°·6	68°·0	61°·1	60°·2	63°·7	77°·9	86°·9	91°·8	89°·7	83°·9	82°·3	82°·4
Cholera	50	20	14	5	8	14	105	128	310	213	192	417	148

Not only does the tendency to cholera decrease as we progress up the Gangetic plains, but so also does the rainfall; for it diminishes from 75 inches at Sagar Island to 65 at Calcutta, 59 at Burdwan, 53 at Berhampore, 40 at Benares, and 37·5 at Allahabad, or only half the amount that falls near the sea coast. As we have already seen, too a larger and larger proportion of the annual average falls between June and September whilst progressing in the same direction. The month of maximum cholera nearly corresponds with the month of maximum rainfall, the maximum of the latter falling in July and of the former in August.

The data regarding the average *hygrometric* condition of the atmosphere at this station are very imperfect; the figures obtainable, however, may serve as a rough guide. According to these the month of maximum cholera corresponds with the month of maximum relative humidity, but the humidity of the next maximum cholera month (May) is less than half that of the other, and the month of minimum cholera corresponds to a month of medium humidity. The maximum *temperature* corresponds with the maximum month of spring-cholera (in May), but the temperature of the actual maximum cholera month for the annual period is 9 degrees lower. As usual, the *minima* of temperature and cholera agree very nearly.

(3) Fyzabad.

It was remarked on a former page that cholera was nearly always present in one or other of the cities of Oudh. The ancient capital (Adjudiah, on the banks of the Gogra) is one of these, and is a place much frequented by pilgrims. The adjoining town of Fyzabad (3 miles distant) is also believed to have more or less cholera constantly present; but as our statistics refer only to troops and prisoners in the latter station, no comparisons can be instituted as to relative monthly prevalence in the district beyond what the figures regarding these communities suggest.

TABLE LVIII.

The average Monthly Rainfall and total Cholera among European and Native troops and prisoners at Fyzabad.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Rainfall [in inches]	6	2″·5	2″·1	2″·3	0″·2	0″·2	0″·1	...	...	8″·7	13″·9	14″·3	8″·6
Cholera	18	71	16	1	1	3	4	133	13	6	6	62	69

The numbers are small, and unfortunately Fyzabad is not a meteorological station, but such information as exists points to the peculiar circumstance that, whilst the district has a reputation for having cholera constantly present in it, the prevalence of the disease among troops and prisoners should approach so closely to what is observed in the endemic area as ordinarily understood, that is to say, getting its largest quantity of cholera, by far, during the dry season. The cases, 133, in April, were not the result of a single year's epidemic, but are the result of a dozen annual visitations out of the 18 years of which we possess records.

The well originally selected for registering the *water-level* appears to have been changed more than once, so that the records are of very subordinate value.

(4) Lucknow.

With regard, however, to the present capital of Oudh, Lucknow, we possess very good data, but these show that the period during which cholera prevails in this city differs from that in Fyzabad, about 80 miles to the east of it.

TABLE LIX.

The average Monthly Water-level, Rainfall, Relative Humidity, Temperature, and the total Cholera among the European and Native troops and prisoners at Lucknow.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.
Water-level [in feet]... ...	6	10′·6	11′·3	12′·4	11′·9	12′·2	12′·8	13′·2	13′·9	14′·6	14′·4	12′·1	10′·7
Rainfall [in inches]	11	1″·27	...	0″·34	0″·99	0″·16	0″·25	0″·19	0″·56	4″·66	14″·10	10″·93	9″·90
Humidity [Sat. = 100] ...		52	44	51	56	48	36	29	37	55	76	76	74
Temperature [°Fahr.] ...	8	78°·5	68°·6	61°·0	59°·9	63°·3	76°·3	86°·7	92°·1	91°·1	86°·1	85°·3	83°·6
Atmospheric pressure ..	8	29·48	29·64	29·69	29·67	29·60	29·50	29·38	29·27	29·14	29·16	29·22	29·32
Cholera	21	58	111	7	1	4	41	63	43	74	329	321	179

According to these data cholera at Lucknow is seen to prevail most during July and August, the number of cases which have occurred in April being less than a fifth

of the July and August cases. Here maximum *rainfall* and maximum cholera correspond accurately, as also the monthly maxima of *relative humidity* and cholera. The *minima*, however, of these do not so closely tally. As usual in the non-endemic area, the minimum *temperature* coincides with the minimum cholera, but the maximum of the latter occurs when the thermometer is on an average six degrees lower than during the hottest month. The maximum of the disease is seen to correspond almost exactly with the minimum pressure, and *vice versâ*.

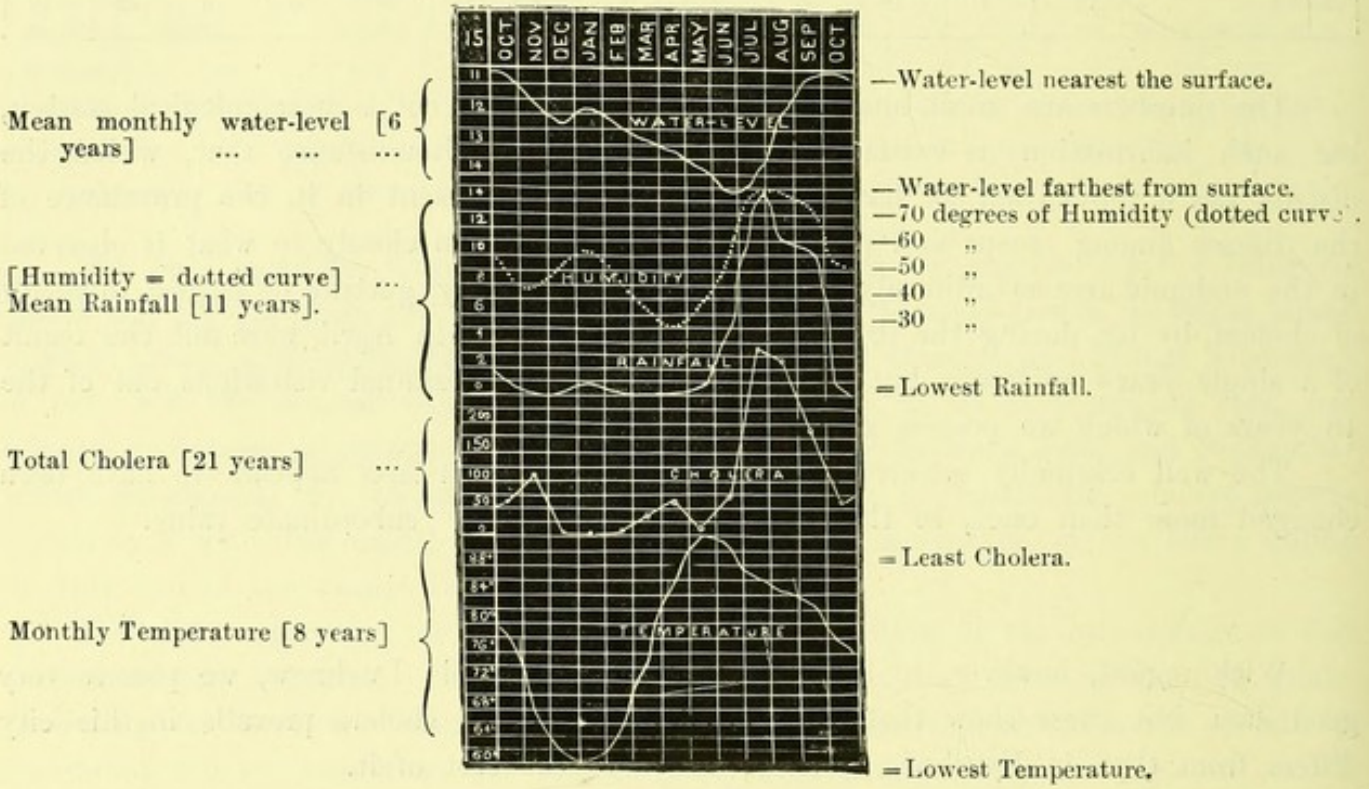


DIAGRAM 15.—The average monthly Water-level, Humidity, Rainfall, Cholera and Temperature at Lucknow.

The *water-level* has been registered by Dr. Bonavia at the Observatory for several years, as also at the central prison some two miles distant, and it has been found that, although a difference of 7 to 8 feet existed between the distance of the water in the two wells from the surface, the fluctuation in the level of the water coincides very closely. It is at its lowest in the month immediately preceding the maximum cholera months, rises on an average about 4 feet between June and October, and then begins to fall again.

The soil within a few feet of the well at the Observatory is sandy, with a few fragments of kunkur, and it appears not improbable that it is under the influence of the adjoining river Goomtee.

(5) CAWNPORE.

Returning to the banks of the Ganges once more we come to the large civil and military station of Cawnpore, which with the city close by furnishes a population of

over 100,000. Records have been kept at this station of the cases of cholera that have occurred among the troops and prisoners for more than half a century, and these now form an aggregate of 4,437. Nearly a fourth of the entire number of cases has occurred during the month of August, although the number of annual visitations of the disease was greater in the month of June, the latter month having furnished 653 cases in the course of 39 annual visitations, and the month of August 1,246 cases in the course of 37. The percentage of spring cholera is still less than at Allahabad, being 35·9 in the latter and 22·4 in the former, and the rainy-season cholera is increased in nearly the same proportion as the spring cholera is diminished.

TABLE LX.

The average Monthly Rainfall and the total Cholera among the European and Native troops and prisoners at Cawnpore.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Water-level	...	Highest	register	ed level	of select	ed well	= 36 fe	et.					
Rainfall	20	0″·80	0″·09	0″·15	0″·66	0″·48	0″·24	0″·09	0″·56	3″·38	9″·24	7″·80	5″·40
Cholera	51	111	82	75	42	39	203	287	424	653	834	1,246	441

(6) AGRA.

Crossing over to the Jumna, we select as an illustrative station the still larger city of Agra. Here also the cholera statistics of troops and prisoners have been collected over a period of 51 years and now furnish a total of 3,501 cases, 3,039 of which have occurred during the rainy season, and nearly a third during the month of August alone.

The months in which cases of cholera have most frequently occurred are August and May, the former month showing cholera on 39, and the latter on 28 occasions.

The aggregate of cases occurring in May is, however, 9 times lower than that of August.

TABLE LXI.

The average Monthly Water-level, Rainfall, Relative Humidity, Temperature, Atmospheric Pressure, and the total Cholera among the European and Native troops and prisoners at Agra.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Water-level	...	Highest	register	ed level	in select	ed wells	= 52 fe	et.					
Rainfall [in inches] ...	22—25	0″·22	0″·03	0″·16	0″·71	0″·42	0″·24	0″·13	0″·63	2″·89	8″·86	7″·24	4″·88
Humidity [Sat. = 100]	7	44	39	48	52	46	37	27	27	46	70	74	70
Temperature [°Fahr.]	8—9	78°·5	69°·5	62°·0	59°·1	65°·1	75°·9	86°·5	92°·5	93°·0	85°·8	83°·4	82°·7
Atmospheric pressure	8—9	29·30	29·46	29·50	29·49	29·42	29·32	29·21	29·09	28·96	28·97	29·03	29·13
Cholera	51	50	32	19	11	13	70	117	150	832	683	1,391	133

The relation of cholera to the *rainfall* (a still greater quantity of which falls between June and September) is pretty nearly the same as at Cawnpore, and the month of maximum relative *humidity* also coincides with the maximum cholera month. The remarks made regarding the relation to temperature in the two last stations apply equally here.

(7) Meerut.

The only other station which we propose to select in the North-Western Provinces is that of Meerut, a large military and civil station situated between the Jumna and the Ganges, some 30 miles from either. The cholera statistics of this station comprise a long series of years and furnish an aggregate of 2,596 cases registered among troops and prisoners, a large proportion of the former being Europeans.

TABLE LXII.

The average Monthly Water-level, Rainfall, Relative Humidity, Temperature, Atmospheric Pressure, and total Cholera among the European and Native troops and prisoners at Meerut.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.
Water-level [in feet] ...	6	10'·4	10'·8	11'·1	11'·4	11'·5	11'·6	12'·1	12'·6	12'·7	12'·6	11'·5	10'·7
Rainfall [in inches]	20	0''·22	0''·2	0''·21	0''·72	0''·84	0''·56	0''·39	0''·93	3''·78	9''·70	6''·71	4''·01
Humidity [Sat.=100] ...	2	47	44	52	53	46	39	28	36	48	72	72	67
Temperature [°Fahr.] ...	4—5	73°·6	66°·5	59°·3	56°·9	63°·2	73°·9	85°·5	89°·2	92°·3	85°·5	84°·0	82°·5
Atmospheric pressure ...	2	29·17	29·34	29·38	29·35	29·31	29·17	29·07	28·95	29·33	29·35	28·91	29·01
Cholera	51	66	68	36	19	16	60	132	126	161	407	1,055	450

The *water-level* registers for Meerut are very complete, and have been conducted by Dr. W. Moir since 1871. The fluctuation coincides very closely with the rainfall. In June the water is at its lowest; it rises a little after the heavy rain of July and August, but scarcely varies two feet during the whole year. It is at its highest level towards the end of October. The data of relative *humidity* are not very satisfactory, but such as they are, they show that, as very generally elsewhere in the non-endemic area, the greatest humidity coincides with the maximum cholera, but the least humidity not with the minimum cholera.

The *temperature* is highest in June, a month later than at the majority of the stations of this area hitherto referred to.

The cholera-history of this station shows that the rainy season—even three months of it, July to September—has furnished more than half of the total cholera; 1,055 out of the 2,596 having occurred in August alone. It obtains a larger proportion of its total *rainfall* during the earlier months of the year (January to May) than the stations lower down in the non-endemic area of the Gangetic plain. In other respects

no marked deviation is observed. Its mean annual rainfall is the same as that for Cawnpore.

The minimum *temperature* coincides generally with the minimum cholera, but the reverse does not hold good. Here, again, the month of minimum *pressure* corresponds with the maximum of cholera.

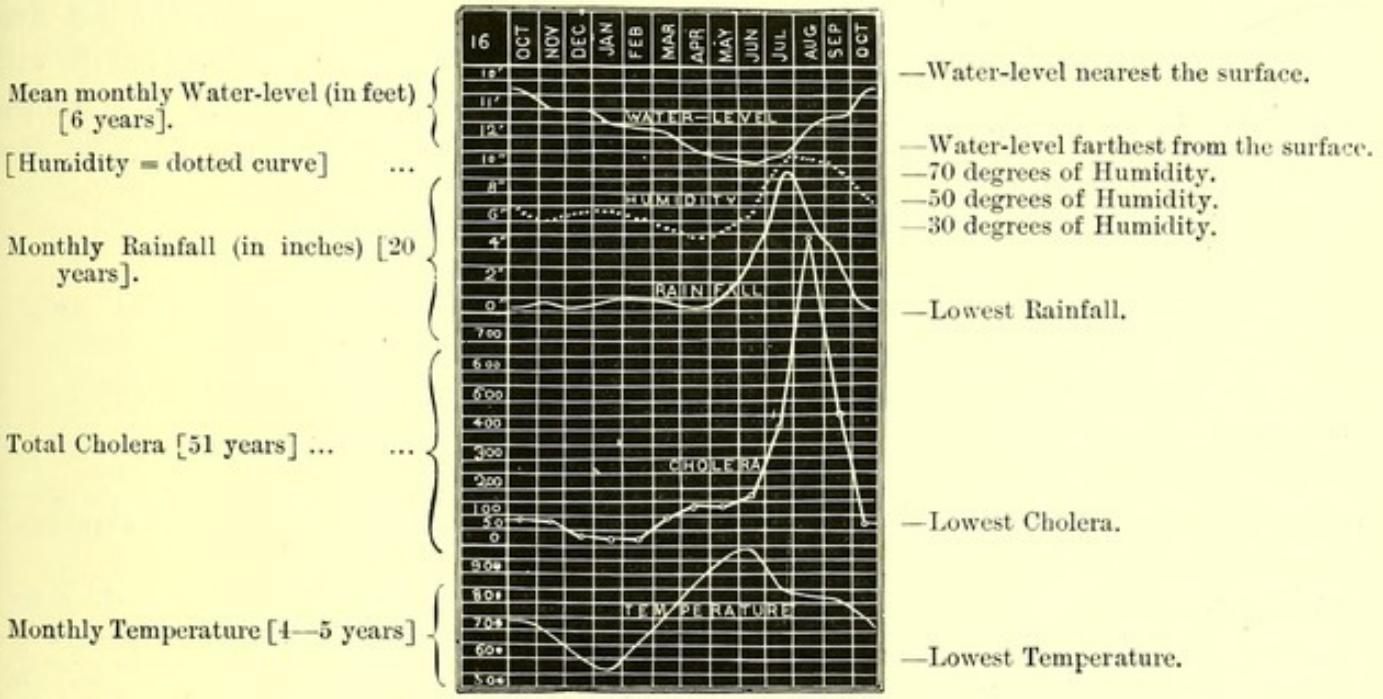


DIAGRAM 16.—The average monthly Water-level, Humidity, Rainfall and Temperature, and the total Cholera at Meerut.

(b) Selected stations in Rajputana, Bundelcund and the Central Provinces.

(1) MORAR, JHANSIE, SAUGOR.

Before pushing up any further towards the north-west a few words may be said regarding some of those stations included in our list, such as Jhansie and Morar, occupying those large alluvial tracts (with black cotton-soil) which spread out from Agra towards Gwalior and southwards.

Of the 726 cases of cholera which have occurred among the troops in *Morar* during the 17 years of which records exist, 438 have occurred during annual visitations in the month of August, and 90·2 per cent. of the total during the rainy season. At *Jhansie*, again, of the 166 cases recorded during 22 years, 99·4 per cent. occurred within the same seasonal period, 134 being in the month of August. The Jhansie rainfall returns have been adopted for both stations, according to which July and August are the rainiest months, 12 inches falling in the former and 9 in the latter.

The cholera-history of *Saugor* also—150 miles to the south—is practically the same, August again taking the foremost place, the next months being October and September, followed by May, with 30 cases against 88 in August.

(2) JUBBULPORE.

Proceeding another 100 miles or so southwards, we come to the large station of Jubbulpore in the Central Provinces. Here the month of August loses its place, for out of 690 cases of the disease recorded among troops and prisoners during the last 21 years, 340 occurred in July. By inadvertence the cholera returns which had been furnished regarding the general population with the water-level registers for the last five years, were included in the statistics of this station in the previous tables, but it will be seen that in the accompanying table the troops and prisoners have been shown separate from the general population. In both instances it is July that occupies the first place as to cholera-prevalence.

TABLE LXIII.

A statement of the average Monthly Water-level, Rainfall, Relative Humidity, Temperature and the total Cholera at Jubbulpore.

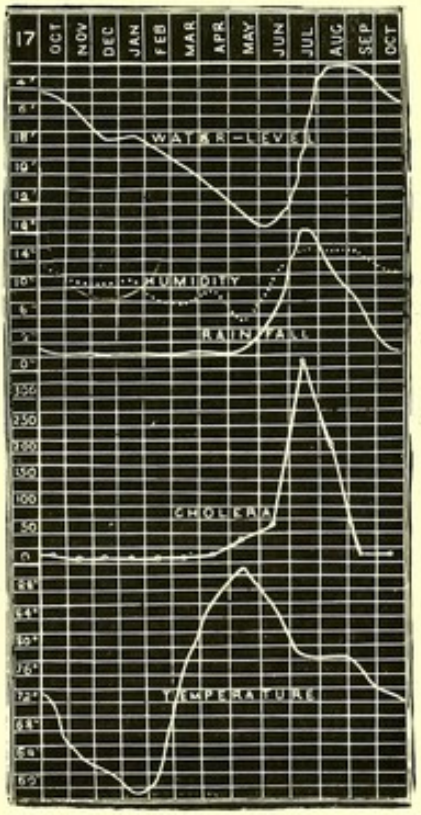
	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.
Water-level [in feet]	6	4'·1	5'·5	7'·7	7'·2	8'·1	8'·8	10'·0	11'·2	12'·5	8'·0	2'·1	2'·1
Rainfall [in inches]	32—33	1''·33	0''·30	0''·19	0''·60	0''·47	0''·46	0''·13	0''·35	7''·66	18''·14	14''·12	8''·53
Humidity [Sat. = 100] ...	10	63	51	50	55	46	37	55	25	52	79	79	78
Temperature [°Fahr.]	7	73°·6	66°·0	62°·0	61°·7	66°·2	75°·1	85°·4	90°·9	86°·7	78°·5	77°·8	78°·5
Atmospheric pressure ...	7	28·50	28·64	28·56	28·62	28·60	28·52	28·42	28·32	28·20	28·20	28·28	28·33
Cholera—troops and prisoners	21	6	1	1	...	1	3	9	44	68	107	34	8
Cholera—general population	5	6	...	...	...	...	...	...	2	...	233	162	5
Total		12	1	1	...	1	3	9	46	68	340	196	13

In looking over the General Table (L), the distinguishing peculiarity that is readily evident is the circumstance that this station gets a heavier mean *rainfall* in July than any of the other stations in the group, its June rainfall also being heavy.

In this station, also, one of the two months of maximum relative *humidity* corresponds with the maximum cholera month; beyond this, however, no close connection can be traced. The month of maximum cholera-prevalence corresponds with one of the months of lowest *atmospheric pressure*, as it was seen to do in other stations of this area, and the maximum pressure agrees generally with the minimum cholera months. The highest monthly mean *temperature*, however, does not coincide with the maximum cholera month, the average temperature of July being 12 degrees lower than the maximum, which occurs in May. The water-level register at this station has been very regularly kept up by Dr. Rice for six years, the monthly mean of which period will be found in the above table. The level of the well is very rapidly affected by the rain-

fall, as may be observed from the fact that it rises nearly 4 feet from its lowest level in June; during the course of July and in August it is within 25 inches of the surface. Hence cholera is at its maximum here when the water is in process of rising from its lowest level.

Whilst these pages were passing through the press, Dr. S. C. Townsend very kindly favoured us with a proof-copy of his report on the cholera epidemic of 1876 in the Central Provinces, and we have availed ourselves of the opportunity of reproducing the monthly returns of the deaths from cholera which were registered in the District of Jubbulpore during the epidemic—from September 1875 to December 1876.



Mean monthly Water-level (in feet) [6 years].

—Water-level nearest the surface.

—Ditto farthest from ditto.

[Humidity = dotted curve] [10 years].

—80 degrees Humidity (dotted curve)

—60 „ „

—40 „ „

—20 „ „

Monthly Rainfall in inches [32-33 years].

= Lowest Rainfall.

Total Cholera, troops and prisoners [21 years] and general population [5 years].

= Least Cholera.

Monthly Temperature [7 years].

= Lowest Temperature.

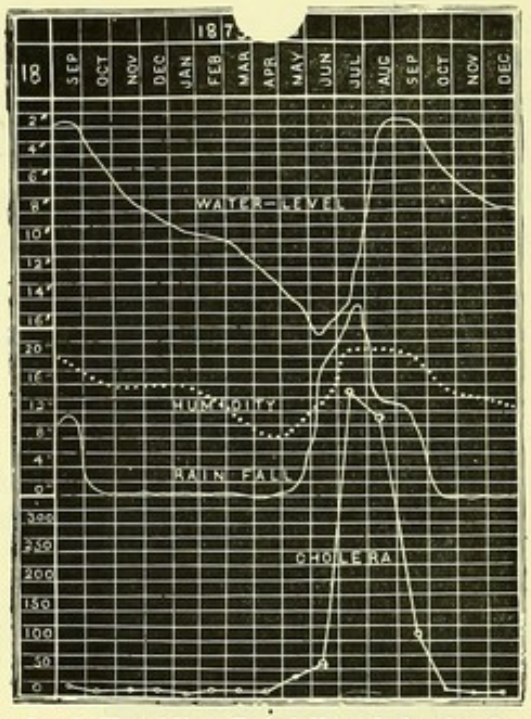
DIAGRAM 17.—The average monthly Water-level, Humidity, Rainfall, and Temperature, and the total monthly Cholera at Jubbulpore.

TABLE LXIV.

A Monthly statement of the Water-level, Rainfall, mean Relative Humidity and total Deaths from Cholera among the General Population of the District of Jubbulpore from September 1875 *to December* 1876.

	1875—1876.															
	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Water-level [in feet] ...	1'·7	4'·3	6'·9	8'·3	9'·1	10'·0	10'·9	12'·7	14'·1	16'·7	13'·9	2'·0	1'·9	4'·9	6'·7	7'·9
Rainfall [in inches] ...	11''·5	0''·8	...	...	...	...	...	...	1''·0	3''·2	27''·2	12''·7	12''·3	...	...	...
Humidity [Sat. = 100] ...	80	67	54	59	57	48	36	22	26	53	84	84	83	64	54	50
Cholera	7	2	...	...	...	...	2	11	48	67	532	492	116	10	...	...

Here also it will be seen that July is the month of maximum cholera, August coming next to it. The monthly water-level, rainfall and relative humidity are also given for the same period.



Monthly Water-level (in feet) [16 months].

Humidity [dotted curve].

Monthly Rainfall [16 months].

Total Cholera [16 months].

—Water-level nearest the surface.

—Ditto farthest from the surface.
—80 degrees Humidity.
—60 ,, ,,
—40 ,, ,,
—20 ,, ,,

—Lowest Rainfall.

—Lowest Cholera.

DIAGRAM 18.—The monthly Water-level, Humidity, Rainfall and deaths from Cholera, from September 1875 to December 1876, at Jubbulpore.

It will be seen in this illustrative chart, also, that the months of maximum humidity correspond with the maximum of cholera; but it will also be noted that cases occurred when the humidity was at its minimum.

(3) RAIPORE.

Water-level returns have been received from other stations in the Central Provinces, but the cholera statistics regarding troops and prisoners are of too limited a character to enable any deductions to be made from them as yet. The jail at the station of Raipore, however, towards the eastern part of the province, has during a period of 22 years furnished a total of 285 cases, and these will be found classified in the general tables according to months and seasons. It is interesting to observe that here also August holds the second place only as to cholera-prevalence, whereas July again holds the first. Raipore, however, has a larger proportion of "spring" cases of cholera (January to May) than Jubbulpore.

(4) NAGPORE.

Nagpore, the chief town of the Central Provinces, situated "on the margin of a broad plain of cotton soil," has not been included in our general tables, as no water-level observations have been taken there, and the data regarding cholera among official communities are very limited, the jail statistics alone being available. These have been collected during 21 years, and an aggregate monthly record of 207 cases of cholera has

been accumulated. July holds the highest position as to prevalence of the disease in this station also, 74 of the total cases having occurred then; but it should be noted that 68 of these cases occurred in the July of one year, *viz.*, 1865. The next highest month of cholera-prevalence is March, furnishing 57, 48 of which are due to two annual visitations during the 21 years, 24 cases in 1856, and 24 in 1864. The jail has been visited by cholera six times during July, five times during March and August. No cases have occurred in December and January, and only one each in February and November.

The foregoing data, however, are far too limited to enable a correct estimate to be made of the seasonal prevalence of the disease in the district—a district which is particularly important in the study of the question of the causation of climatic diseases, seeing that it occupies a somewhat peculiar position as to monsoon influences. Mr. Blanford describing the rainfall of these parts writes: "All through the Mahratta Country, as far as Nagpore, the annual distribution of rain is the same as at Bombay, *i.e.*, practically restricted to the season of the summer monsoon. But from Nagpore eastwards spring storms are not infrequent, and an appreciable amount of rain falls during the earlier months of the year."*

With the object of still further illustrating the cholera of the Central Provinces according to seasons, we again avail ourselves of the proof-copy of Dr. Townsend's report regarding the epidemic of 1875-76, and incorporate the data regarding the cholera mortality of Nagpore in the same manner as was done regarding Jubbulpore. The prevalence of the disease in the district during the epidemic according to months will be found in the following table, as also the monthly distribution of the disease as it has occurred in the Nagpore Jail during the last 21 years.

TABLE LXV.

The monthly prevalence of Cholera at the Nagpore Jail during 21 *years, and the Deaths from Cholera which occurred in the District during the Epidemic of* 1875-76, *together with the average monthly Rainfall, Humidity, Temperature, and Pressure.*

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.
Mean raintall [in inches]...	27	2″·55	0″·55	0″·41	0″·58	0″·61	0″·89	0″·36	0″·61	9″·21	11″·84	9″·11	8″·33
Mean humidity	7	54	46	49	44	39	49	21	23	56	76	74	74
Mean temperature [° Fahr.]	6—7	76°·9	70°·9	67°·8	68°·5	73°·8	81°·9	88°·4	93°·3	85°·9	78°·7	78°·7	78°·9
Mean pressure	7	28·80	28·94	28·97	28·94	28·90	28·81	28·71	28·62	28·53	28·54	28·60	28·65
Total cholera, prisoners ...	21	14	1	...	...	1	57	22	16	5	74	13	4
Ditto, general population	1—2	67	456	30	...	...	...	2	2	1	69	1,642	543
Total cholera ...	...	81	457	30	...	1	57	24	18	6	143	1,655	547

* *Meteorologist's Vade Mecum*, p. 215.

According to these combined cholera statistics August again maintains its position, a sudden rise in prevalence of the disease being observed, followed by a more gradual fall. The month of maximum *rainfall* immediately precedes the maximum cholera month, as also does the maximum *humidity*. The monthly maximum *temperature*, however, precedes the maximum cholera by 3 months, and exceeds the mean temperature of August by nearly 15 degrees. The maximum cholera corresponds nearly with the minimum *pressure* and the maximum pressure very nearly with the minimum cholera.

(c) Selected Stations in the Punjab.

(1) Mean Meer and Lahore.

We have selected three stations in the Punjab, or rather two—Lahore and Mean Meer having been brought together. Mean Meer is the military station of Lahore, about 6 miles to the south-west of it and on higher ground. The cholera returns for the former extend over 25 years, and for the latter over 31, and furnish a total of 2,638.

TABLE LXVI.

The average Monthly Rainfall, Relative Humidity, Temperature and Pressure at Lahore, together with the total Cholera registered among the European and Native Troops and Prisoners at Lahore and Mean Meer.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.
Water-level	...	Highes	t regist	ered le	vel of s	elected	well(at	Mean	Meer)	= 36 fe	et.		
Rainfall [in inches] ...	10	0″·6	...	0″·50	0″·50	0″·91	0″·91	0″·27	0″·92	1″·20	6″·29	3″·89	2″·5
Humidity [Sat. = 100] ...	6	35	39	50	57	52	46	33	24	32	49	53	53
Temperature [°,Fahr.] ...	8—10	76°·7	64°·9	55°·3	53°·4	59°·5	69°·0	81°·2	88°·7	93°·0	88°·3	87°·4	83°·5
Atmospheric pressure ...	2—3	29·11	29·33	29·34	29·28	29·26	29·11	29·03	28·90	28·72	28·74	28·83	28·93
Cholera, Lahore	31	4	2	2	1	1	3	15	3	12	24	491	235
,, Mean Meer ...	25	8	1	1	2	0	1	2	13	14	76	1,489	238
Total cholera ...	...	12	3	3	3	1	4	17	16	26	100	1,980	473

It will be observed that August again stands prominently forward as the month pre-eminently adapted for cholera in these provinces, nearly 2,000 of the 2,600 odd cases having occurred in this month, the maximum both in Lahore and Mean Meer taking place in the same month.

The proportion of *rainfall* from January to May continues to augment as we proceed towards the frontier. At Meerut it was seen to be 12·2 per cent. of the total, and here

it is 18·9. The proportion of cholera, however, during these months does not appear to augment at the same rate.

The mean relative humidity of the atmosphere at Lahore is all the year round very low, and here it is the highest degree of humidity but one, and not the highest, that corresponds with the maximum cholera months. The highest humidity, so far as our data go, appears to correspond with one of the months of minimum cholera.

The month of lowest mean *pressure* here also corresponds very nearly with the month of maximum cholera, and the high pressure months with the months of minimum cholera. As at Meerut, the *temperature* of June is higher than that of May, and is higher than the temperature of the month of maximum cholera by 5°·6.

(2) Peshawur.

We select one more station, that of Peshawur, in the trans-Indus territory of the Punjab. It is a large frontier military station situated in a valley, about 50 miles in length by 40 in breadth, traversed by three tributaries of the Indus.

TABLE LXVII.

The average Monthly Rainfall and the total Cholera registered among European and Native Troops and Prisoners at Peshawur.

	Years recorded.	Oct.	Nov.	Dec.	Jan.	Feb.	March.	April.	May.	June.	July.	Aug.	Sept.
Water-level	...	...	...	Highes	t regist	ered lev	el of sel	ected w	ell = 81	feet.			
Rainfall [in inches]	7	0″·3	0″·3	0″·5	1″·3	1″·2	1″·6	1″·25	0″·6	0″·2	1″·7	2″·6	1″·1
Cholera	28	343	26	...	3	...	1	5	205	164	131	25	577

Unfortunately we have not been able to obtain any very satisfactory meteorological data regarding this station, so that the table merely gives the mean monthly rainfall, and the monthly cholera—the figures representing the latter extending over a period of 28 years. The total *rainfall* of the year is not quite 13 inches, and nearly half of the total falls in the earlier months of the year. The cholera statistics also indicate that the disease is not distributed over the annual period in the same proportion as in the non-endemic area generally, for 40 per cent. of the total cholera at Peshawur has occurred at *other* than the ordinary rainy season of the great part of the North-West and Lower Provinces, *viz.*, June to September.

IV.—GENERAL CONCLUSIONS.

CHAPTER I.

A COMPARISON OF THE PRINCIPAL PHYSICAL CONDITIONS CHARACTERISING THE VARIOUS SEASONS OF CHOLERA-PREVALENCE IN THE ENDEMIC AND NON-ENDEMIC AREAS.

HAVING previously considered the physical features of the various seasons of cholera-prevalence in those parts of the Bengal Presidency in which the disease is endemic and in those in which its occurrence is occasional only, it remains to be seen how far any community of conditions characterises the seasons throughout both areas, how far prevalence appears to be favoured or repressed by definite conditions independent of mere geographical position of locality.

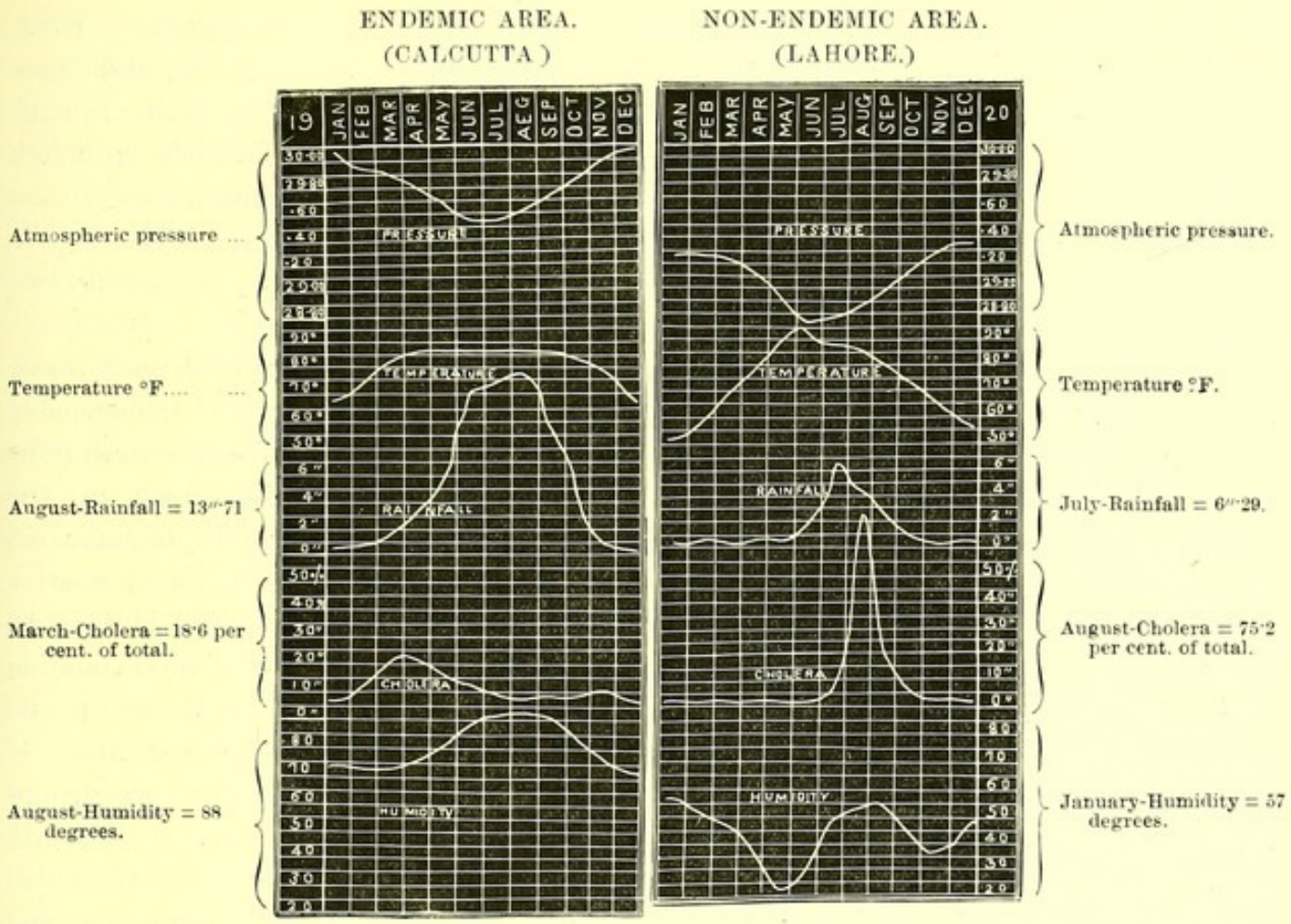
The following table shows the conditions presented by two typical stations, Calcutta and Lahore, which may be regarded as presenting extreme examples of the characteristics of the endemic and non-endemic areas, both in regard to physical features and cholera-prevalence.

TABLE LXVIII.

Showing the Physical conditions associated with various degrees of Cholera-prevalence in Calcutta and Lahore.

	ENDEMIC AREA (CALCUTTA).											
PHYSICAL CONDITIONS.	Jan.	Feb.	Mar.	April.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.
Atmospheric pressure...	30·01	29·94	29·85	29·75	29·66	29·55	29·54	29·60	29·68	29·83	29·98	30·03
Temperature	67·7	73·0	80·5	84·7	86·2	84·9	83·5	83·1	83·3	81·5	74·9	68·1
Humidity	68	68	67	73	75	83	87	88	87	80	71	68
Rainfall (inches) ...	0·44	0·83	1·28	2·49	5·46	12·13	12·64	13·71	10·17	5·61	0·66	0·24
Water-level (feet) ...	Average lowest, May, 14′·6. Average highest, September, 8′·2.											
Percentage of total cholera *	3·13	7·04	18·68	17·52	11·98	8·81	8·01	3·97	4·90	5·07	6·80	4·03
	NON-ENDEMIC AREA (LAHORE).											
Atmospheric pressure...	29·28	29·26	29·11	29·03	28·90	28·72	28·74	28·83	28·93	29·11	29·33	29·34
Temperature	53·4	59·5	69·0	81·2	88·7	93·0	88·3	87·4	83·5	76·7	64·9	55·3
Humidity	57	52	46	33	24	32	49	53	53	35	39	50
Rainfall (inches) ...	0·50	0·91	0·91	0·27	0·92	1·20	6·29	3·89	2·54	0·6	0·0	0·50
Water-level (feet) ...	Lowest 37′·0. Highest 36′·0.											
Percentage of total cholera *	0·07	0·00	0·15	0·65	0·60	0·98	3·80	75·22	17·97	0·45	0·03	0·03

* European and Native troops and prisoners.



DIAGRAMS 19 and 20.—Illustrative of the mean monthly Physical Conditions and the prevalence of Cholera in the Endemic and Non-Endemic areas—Calcutta and Lahore. (The Calcutta Cholera-curve has been cut a space too high throughout in the diagram.)

Taking these stations as affording indices of the general characters of the areas in which they lie, we find certain marked apparent contrasts between them in regard to the conditions coincident with maximum and minimum prevalence. Maximum prevalence in Calcutta occurs coincidently with relatively high atmospheric pressure and with low humidity and rainfall: whilst in Lahore it is associated with precisely the opposite conditions.

The data in the Bengal Presidency afford no ground for supposing that *atmospheric pressure* exerts *per se* any appreciable influence on prevalence; and the contrasts presented by the endemic and non-endemic areas in this respect must be regarded as entirely subordinate to those of relative humidity and rainfall.

With reference to atmospheric *temperature* in place of contrast there is agreement, and it is corroborative of belief in the actual existence of an influence of temperature on cholera-prevalence to find, that very much in proportion to the increase in the difference between the temperature of the various seasons there is a corresponding increase in the difference of prevalence occurring in them.* In

* It will be observed that no special notice has been taken of the question of *range* of temperature, as a characteristic of the various seasons. This is not the result of an omission, but as the only thing that

Calcutta the range of temperature between the coldest and warmest month is 18°·5, in Lahore it is 39°·6, or, stated in reference to prevalence, in Calcutta the difference between the temperature of the month of maximum cholera and the coldest month is 13°·8, while in Lahore it is 34°·0. In Calcutta there is a considerable reduction of prevalence in the coldest month as compared with that of the maximum prevalence —the percentages of total cholera being 3·13 and 18·68; but this is reduced to insignificance as compared with that exhibited in Lahore, where the respective percentages are 0·07 and 75·22.

In reference to *humidity* we find apparent contrasts very sharply defined, more sharply even than those exhibited by the conditions of rainfall. It is questionable how much this difference ought not to be regarded as a mere subordinate concomitant of that in regard to rainfall; but in so far as atmospheric humidity itself can be supposed to exert any influence on prevalence of the disease, it must be remembered that the contrast lies not so much in absolute conditions of humidity as in relative local conditions. The fact is that the conditions of atmospheric humidity of the two localities come to approximate most closely at different seasons—the approximation occurring when the humidity of Calcutta is at its lowest and that of Lahore at its highest. Putting January and February aside as months in which conditions of temperature exert a disturbing influence on prevalence, we find that the conditions of humidity in Lahore, most closely approaching in degree those present in Calcutta during March and April, are those of August and September. The contrast presented by the two localities, then, in reference to conditions of atmospheric humidity and cholera-prevalence is one in regard to relative local conditions only, the absolute humidity of the localities during their seasons of maximum prevalence is comparatively similar. The same final result may be obtained by addition in one case and by subtraction in another, according as the basis of calculation is greater or less.

This must be borne in mind in reference to the next point also—the contrast between the conditions of *rainfall* associated with prevalence of cholera in the two localities.

In considering the physical conditions of Calcutta we found reason to regard the influence of rainfall as a mediate one, acting through the agency of its direct effects on the soil. In Calcutta, no doubt, the influence of rainfall appears to be mainly exerted through its effects on soil-ventilation, and here there can be no question as to the existence of an apparent contrast between the conditions coincident with maximum prevalence in the two localities. In so far as rainfall acts in obstructing soil-ventilation there is certainly a manifest contrast between the conditions coincident with maximum prevalence in Calcutta and Lahore. The rainfall in the two localities is, however, so very dissimilar, that even were their soils precisely identical in

could be said regarding it is, that mere range of temperature exerts no appreciable influence on the prevalence of cholera, it has not been deemed necessary to occupy space in giving detailed data leading to no further conclusion.

nature, similarity in their effects could not be looked for. The effects on soil-ventilation produced by a fall of 3″·89, which is the average amount for August in Lahore, must patently be very different from those of the contemporaneous fall of 13″·71 in Calcutta.

Direct observations are still wanting on the effect of the rainfall in the stations of Upper India on conditions of *soil-ventilation;* but the data furnished by the present example are sufficient to show that it is idle to found conclusions on comparisons of local relative conditions, and that it is the absolute conditions, coincident with various seasons of cholera-prevalence, which must be compared with one another. The rainfall and soil of one place may be such that maximum rainfall effectually interferes with soil-ventilation, whilst in another they are so different that little or no effect is produced.

Rainfall, however, may influence the local prevalence of cholera by means of its influence on the soil in various ways. It does not only act on the ventilation of the soil, it also acts on its conditions of moisture, and, indeed, it is only in doing so that it affects the ventilation. If the development of the cause of cholera in a locality be dependent on local conditions of soil, as there is much reason to believe is the case, it is surely conceivable that one of these conditions is a certain degree of moisture. Granted this, and there can be no difficulty in assuming that given localities may fail to produce cholera either on account of the soil being too damp or too dry, and that the conditions ensuring development might be provided in one case by diminishing, in the other by increasing, the amount of moisture present. Looked at under this light, the apparently contrasted conditions of rainfall coincident with maximum prevalence of cholera, in stations such as Calcutta and Lahore, practically disappear. As in the case of the humidity, the contrast is one between local relative conditions only, not between the final result of the action of these conditions, or even between the absolute conditions themselves.

In regard to water-level little need be said, as it has been already indicated that, in this country, data of rainfall are more generally applicable as indices of conditions of local soil-moisture than fluctuations in water-level can be.

Calcutta and Lahore have been selected as typical examples of localities in the endemic and non-endemic areas, regarding which we have relatively satisfactory data for comparison. The remarks made regarding them are, however, generally applicable to the other stations within these areas. Calcutta and Lahore are no doubt extreme examples of the characteristics of these areas, both in regard to seasonal distribution of cholera-prevalence and to the coincident physical phenomena, and the phenomena of every locality must be scrutinized in detail for themselves. Lahore is peculiarly distinguished by the smallness of its rainfall, and many other stations within the non-endemic area may be pointed out where the season of maximum cholera is coincident with considerable rainfall. The evidence of the influence of soil-ventilation on prevalence is certainly not so manifest in these cases in regard to Calcutta.

Before any conclusion can be arrived at, however, on this point, data derived from direct observation regarding the actual influence exerted on the soil-ventilation must be acquired, and in the meantime it is well to bear in mind that we have no evidence to show what the effect of the addition of moisture to the soil without coincident obstruction to soil-ventilation might be. We do know how much cholera arises under existing circumstances; we can form no conception as to what the amount might be under the hypothetical ones.

CHAPTER II.

THE PHENOMENA OF SEASONAL FLUCTUATION IN THE PREVALENCE OF CHOLERA CONSIDERED IN REFERENCE TO THE PRINCIPAL THEORIES REGARDING THE ESSENTIAL CAUSE OF THE DISEASE.

(a) As observed in Calcutta.

In the earlier part of this report an attempt has been made to ascertain the character of the local physical conditions coinciding with the various degrees of cholera-prevalence in Calcutta at different times during the course of the year. The information thus obtained has next to be considered in reference to various current theories relative to the essential causation of the disease.

The most important theories are the following:

1*st.*—That which regards cholera as essentially caused by direct contagion,—by the direct transfer of a poison, manufactured within the human organism, from one person to another. According to it, any fluctuations in the prevalence of cholera must be dependent on corresponding fluctuations, either in opportunity of transfer, or in the susceptibility of human beings to the influence of the poison.

2*nd.*—The so-called "water theory." In this, also, the human organism is regarded as the factory in which a specific poison is produced. By one set of the supporters of the theory, water is regarded merely as one means—although by far the most important and influential means—by which the poison is diffused,—is transferred from one person to another. By other authorities, however, water is not regarded as a mere vehicle, but as the medium in which the material produced within the human organism attains its maximum of virulence. According to this theory, fluctuations in the prevalence of cholera must essentially depend on corresponding fluctuations in conditions determining, or facilitating, the transfer of materials produced within the human organism to the water, and specially to the drinking water.

3*rd.*—The theory which, while regarding the drinking water of a locality as essentially determining the prevalence of cholera in it, does not regard its influence as necessarily dependent on the introduction of any specific material manufactured

within the bodies of those suffering from the disease. It holds that the drinking water determines prevalence, both by its effect on personal susceptibility, and by being the essential medium in which the specific poison is developed. In any case, the quality of the drinking water of a locality is regarded as the essential determinant of the fluctuations in the prevalence of cholera in it at different periods. Any fluctuations of prevalence in localities in which cholera is endemic are regarded as depending on corresponding fluctuations in the quality of the water, increase and decrease in prevalence being due to increase and decrease in the impurity of the water.

4th.—The theory which regards the soil as the essential site of the processes resulting in the production of the material inducing cholera. The majority of the adherents of this theory regard the air as the vehicle, by means of which the material produced in the soil is conveyed to human beings, so as to cause the disease in them; but it is obvious, that questions of vehicle are really subordinate here, and that materials manufactured in the soil may reach the human subject by more than one path. According to this view, fluctuations in prevalence of cholera are dependent on corresponding fluctuations in the condition of the soil, which may act either on the manufacture or the diffusion of the specific materials.

We have now to inquire how far each of these theories is capable of accounting for the phenomena of seasonal fluctuations exhibited by the prevalence of cholera in Calcutta.

1st.—The theory of direct contagion. It may be deemed superfluous, at the present day, to enter into the serious consideration of this doctrine, still as it is yet advocated by some whose opinions are entitled to respect, it is necessary to determine the bearing of our data upon it. The normal course followed by the fluctuations in the prevalence of cholera in Calcutta is not merely inexplicable by this theory, but is strongly opposed to it. If prevalence were dependent on direct contagion, the maximum prevalence should occur at those times of year when the population is most liable to close association. As a fact, the maximum prevalence in Calcutta occurs during a period when there is less crowding together, or close association of the population, than in either of the periods immediately preceding and following it. The native population is more crowded together during the height of the cold weather and of the rains than at any other time of year; for it is then that the people are obliged—by the temperature in the one case, by the rainfall in the other —to pass the nights packed together in their houses, instead of spending them largely in the open air. According to this theory, the prevalence of cholera ought to attain its maximum in December and January, and in July and August; but, in place of this being the case, these are precisely the periods during which prevalence of the disease is at its lowest ebb.

2nd.—The "water-theory," as ordinarily understood. This theory, also, fails to explain the phenomena of seasonal fluctuation in prevalence, or to gain any

support from them. According to it, maximum prevalence ought to occur at that period of the year when the meteorological conditions are of a nature calculated to facilitate the entrance into the drinking water of materials derived from the bodies of those suffering from the disease, and specially of the materials of the intestinal excretions. The period during which most material is washed into the tanks and other bodies of water, which, until quite recently, constituted the universal sources of drinking water in Calcutta, is, that of those months in which the rainfall is greatest and characterised by the greatest heaviness of individual falls. These months are June, July, August and September; but the first of these is a month of low medium, while the three others are months of minimum prevalence. With reference to the latter three months, it may be argued, that although the inwash of materials is then great, the inwash of the specific material producing cholera is not so, as it has been in great part removed from the surface of the soil by previous rainfall, and that the influence of what still remains to be introduced is neutralised by the coincident dilution of the sources of drinking water.

This argument is, however, quite inapplicable to the phenomena of June. At this time there has been no sufficient previous rainfall to remove the specific material from the soil surface, or to dilute the water supply; and yet the abundant and violent rainfall of June is accompanied by a great decrease in prevalence. Equally inexplicable on this theory are the phenomena presented by May and November. In May the amount of specific material ready for introduction must be at a maximum, for the preceding months are those in which the number of cases of the disease—the number of assumed factories of the poison—far exceeds that present at any other time of the year. In May, too, both the total rainfall and the heaviness of individual falls are, on an average, higher than in April; and yet at this very time, when everything, according to the theory, provides for excessive increase in prevalence, there is, on the contrary, a marked decrease. We have here an instance of decrease where the theory requires increase, and the phenomena of November furnish an example of an exactly opposite nature—furnish an instance of meteorological conditions which, according to the water theory, ought to ensure decrease, but which, in fact, coincide with marked increase. When we compare the rainfall of November with that of October, we find that, in so far as provision of means securing inwash of materials is concerned, the latter month occupies a much higher place than the former; and yet the virtually rainless November shows a great increase in prevalence when compared with October.

3rd.—The theory which regards the degree of impurity of the drinking water as the essential determinant of the prevalence of cholera. According to this theory, the periodic fluctuations in the prevalence of cholera in a locality in which the disease is endemic are dependent on corresponding variations in the degree of impurity of the water-supply. In so far as the general physical conditions of locality are concerned, the degree of impurity of the water must depend on the degree to which the entrance

of extraneous impurities is facilitated, and on influences determining the relative proportions of the impurities to the mass of water containing them. The conditions favouring the entrance of foreign matters in general into the sources of water-supply are precisely those described previously as favouring the entrance of specific materials; and the conditions favouring concentrations of impurity are those under which the general mass of water is reduced to least bulk. Consequently, according to this theory, the maximum prevalence of cholera in Calcutta ought to occur during the hot and dry season, when concentration attains a maximum, and during the commencement of the rains, when there is great inwash of extraneous impurities, without an increase in the mass of the water, calculated to do more than neutralise this addition.

The phenomena presented by the cholera-prevalence of the hot and dry months, at first sight, appear to afford strong confirmatory evidence to the theory; for the season of maximum prevalence occurs then, coincidently with the season of lowest water-level. When, however, the phenomena of individual months of the hot and dry season are examined, the results are not so favourable to it. In May the water-level reaches its lowest, the conditions affecting evaporation being, apparently, more than sufficient to neutralise the effect of the slight excess in the rainfall over that of April. In May, then, the sources of water-supply are reduced to their smallest bulk, and the concentration of the impurities in them reaches a maximum; and consequently, according to the theory, the cholera-prevalence of the hot and dry season ought to come to a climax then. On the contrary, however, the prevalence in May is much less than in either of the preceding months.

The phenomena of June do not show any close agreement with the requirements of the theory. At this time, according to the theory, cholera-prevalence ought to continue at a maximum; for, although the mass of water in the sources of water-supply undergoes considerable increase, the conditions of rainfall are such as to ensure great inwash of materials from the soil, which has not been purified by any great previous rainfall. June is, however, a month of low medium—not of maximum prevalence. November, also, presents great difficulties to the acceptation of any such explanation of the phenomena of periodic fluctuations in prevalence. In November conditions facilitating inwash of extraneous materials are at a minimum, and the mass of water is greater than in either June or July. The prevalence in November ought, therefore, to be lower than that in June and July; but, on the contrary, it is very much higher than in these months.

4th.—The "Soil-theory." The theories which have been considered hitherto assume that the nature of the specific cause of cholera, or, at all events, that the conditions determining the production of the specific cause, are already definitely ascertained. The soil-theory, however, does not go so far; and the difficulty of determining the bearing of our data upon it is proportionately enhanced thereby. All that it definitely affirms is, that the specific cause of cholera is developed in the layer of soil lying

above the water-level or first impermeable stratum in a locality; and that, therefore, the development must depend on certain conditions of that layer. These conditions are, admittedly, quite undetermined, but must be supposed to be constantly existent, in greater or less degree, within the areas in which the disease is endemic. According to it, fluctuations occur either in conditions affecting the development of the poison in the soil, or in conditions determining its diffusion from the soil.

So long as the conditions supposed to secure development of the poison are not distinctly defined, it is evident that an endemic locality affords little field for testing the theory in regard to the relation of prevalence of the disease to influences calculated to favour its production. Attention must, therefore, be mainly directed to prevalence regarded as dependent on diffusion; but even regarding questions of production, there are certain phenomena of prevalence, which admit of comparison with the theory. In any locality, like Calcutta, where the layer of soil above the water-level is always of comparatively little depth, and of tolerably uniform structure throughout, the theory may be supposed to assume, that, other things being equal, the amount of the specific material developed ought to increase with the mass of generating stratum. From this point of view, the maximum and minimum of prevalence ought to coincide with the maximum and minimum depression of the water-level, which is very much what we have previously ascertained to occur in reality.

In proceeding to consider cholera-prevalence as an expression of the degree of diffusion of the poison, it must be borne in mind that there are two main channels by which materials developed in the soil may reach human beings in any locality. These are the water and the air occupying the interspaces between the solid constituents of the soil. If the water of the soil be regarded as the means of diffusion of the poison, the phenomena of prevalence in Calcutta present the same difficulties to this theory as they do to those previously considered. This, however, is not the case if the air be regarded as the channel traversed by the poison in passing from the soil to the subjects of the disease. On this hypothesis, maximum and minimum of prevalence ought to coincide with maximum and minimum of soil-ventilation. According to our data, the maximum of soil-ventilation occurs during March and April, coincidently with the maximum of prevalence; and minimum soil-ventilation occurs during the rainy season, the period of minimum prevalence. So far, however, as diffusion alone is regarded as determining prevalence, the phenomena of prevalence in Calcutta do not coincide accurately with the requirements of the theory. The depression of prevalence in December and January, and again in May, remains inexplicable; and all that can be positively affirmed is, that the difficulties opposed by the phenomena of periodic fluctuation in the prevalence of cholera in Calcutta to the soil-theory, are less than those encountered by any of the other current doctrines regarding the essential cause of the disease.

It will be observed, that in the previous pages no special notice has been taken of the great and persistent diminution in the prevalence of cholera in Calcutta during

the last few years. This has been done designedly, in order to avoid complications, incident on the discussion of two different questions simultaneously. The present report deals with phenomena, which are common both to the period previous to, and to that following, the diminution. To have attempted to combine the discussion of the cause of the diminution in absolute prevalence with one regarding the cause of the variations in relative prevalence characterising different periods of the year, could only have led to confusion and obscurity.

(b) As observed in the localities in the Endemic area other than Calcutta.

The foregoing remarks apply with equal force to the relation which various physical conditions bear to the prevalence of cholera in the other districts in the Bengal Presidency in which the disease may be said to be endemic. It will have been observed that in the stations which have been selected to represent the principal districts in the endemic area taken as a group, the seasonal manifestation of the disease presents a striking resemblance to that in Calcutta—82 per cent. of the total annual cholera taking place during the eight drier months of the year in Calcutta, and 71·2 in the stations taken as a group, the maximum cholera in both occurring during the comparatively dry months of March and April. [*Vide* Table LIV.]

As, however, the figures available regarding the prevalence of the disease at the individual stations of this group are so small compared with the statistics in Calcutta, which embrace the general population, it is not to be expected that the monthly proportions should accurately agree. Nothwithstanding this, however, and the difference in the surroundings of the classes of the population compared, even the monthly statistics, especially when weeded of manifestly casual occurrences, present a marked general similarity. It is therefore obvious that the conclusions derived from the data regarding Calcutta apply generally to this group of stations also.

(c) As observed in the Non-Endemic Area.

Seeing, however, that in those parts of the Bengal Presidency in which cholera manifests itself at irregular intervals only, it displays a preference for other than the dry months of the year, it will be necessary to consider whether the foregoing remarks concerning the more prominent doctrines regarding the causation of the disease still retain their applicability.

(1) With regard to *the theory of direct contagion*, it was observed that the fact that cholera-prevalence in the endemic area was at a minimum when, for climatic reasons, the people (during the rainy and cold seasons) were most crowded together, tended to negative the view that personal contact exercised any important element in the extension of the disease.

In the Upper Provinces, notwithstanding the still closer relation which must exist between individuals owing to the greater severity of the cold, cholera falls to its

minimum degree of prevalence at the period of minimum temperature, and a sudden diminution from the maximum prevalence of cholera takes place contemporaneously with the setting in of the colder weather. On the other hand, close association of individuals must also be favoured by the crowding incident on the conditions of the rainy months of the year when cholera is most apt to occur. As, however, the heavier and more continuous rainfall of Lower Bengal, with the correspondent increased crowding together of the people, is contemporaneous with a marked diminution of the disease, the general weight of evidence remains opposed to the doctrine of direct contagion.

(2) Assuming the water-level registers to give a fair general indication of the fluctuation of the water used for domestic purposes in the different stations where observations were conducted, the theory of the spread of the disease through the medium of drinking-water gains greater support in the non-endemic area than in Lower Bengal. A glimpse at the diagrams representing the variation in the water-level of different localities in this area will show that the disease undoubtedly attains its maximum shortly after the level of the water in the wells begins to rise; hence, it might be inferred, when sufficient time has elapsed for the choleraic material dispersed over the soil to find its way by percolation into the wells, and when the water, being low, favours the swallowing of the *materies morbi* in a concentrated form. To this, however, it must be added that a considerable proportion of the cholera of a station occurs before the water-level in the wells is affected, especially in some stations where the wells are very deep, and where the total annual fluctuation does not exceed a few inches. In such cases it must be assumed, either that the cause of cholera was present in the water before the percolated impurities could reach the well, or that the earlier cholera of the season was derived from some other source than that furnishing the later cases. With regard to the production of the "spring" cholera, again, it can hardly be attributed to the percolation of choleraic impurities into the wells; for the ground appears to absorb all the rain that falls at this time, and in scarcely any of the selected stations in the non-endemic area is it observable that the level of the well-water is materially affected by this season's rainfall.

It may, of course, be maintained that while all cases of cholera are not to be referred to the effects of the *percolation* of choleraic impurities into sources of drinking water, those phenomena which cannot be accounted for in this way are ascribable to the effects of the *direct introduction* of the materials into the water, or other ingesta. But before this can be accepted as a satisfactory explanation of the phenomena, it must be shown that the facilities of introduction at different seasons and in different years vary proportionately to the coincident prevalence of cholera. Until this has been done, the theory seems to assume, that every year in which cholera is generally epidemic, is at the same time a year in which there is an epidemic tendency to the direct introduction of choleraic materials into sources of water supply.

The streams and rivers must, however, receive a considerable amount of surface impurities by every fall of rain; and if it were true, as some advocates of the "water-

theory" maintain, that an infinitesimal quantity of a choleraic discharge finding its way into a river can multiply to such an extent as to be capable of infecting the population of an entire city, a rapid and general diffusion of cholera would be readily accounted for. If this were actually the case, however, it should follow that the progress of cholera along the water-courses and in the direction of the current would be evident to all. In that case, any outbreak of cholera which might occur in the earlier part of the year towards the north-west of the area under consideration, ought to be traceable week by week along the line of the streams and rivers which flow into the Ganges in the North-West Provinces, Oudh, Behar, and so on, in a direction towards the sea; but experience shows that, so far as the disease can be tracked in any definite direction—that is to say, so far as the circumstance that the months of maximum cholera-prevalence present a certain ill-defined, progressive arrangement along the stations in the Gangetic plain, can be taken as indicative of the "direction" taken by the disease—this direction is precisely the reverse of that followed by the numerous streams and rivers; cholera attains its maximum in March and April towards the mouths of the Ganges, but not till August at its sources.

(3) In so far as the endemic area is concerned, there can be no doubt that the soil-theory is more in accordance with the phenomena of the seasonal prevalence of cholera than any of the other theories previously considered. In regard to Upper India the evidence is as yet defective, and detailed data are wanting on many points. There are, however, certain important facts pointing very distinctly to the importance of local soil-conditions in relation to cholera-prevalence in this area also.

It was remarked, in one of the earlier chapters of this paper, that the nearer the soil of a district in India approaches in character that constituting the lower portion of the Gangetic plains, the greater is the likelihood that cholera will be found as an endemic disease in it. It has been seen that the seasonal manifestation of cholera changes gradually as we proceed up the river, the disease manifesting a tendency to be deferred later and later in the year the farther the affluents of the Ganges are followed towards their sources, and the drier the climate and the soil become, so that in the upper part of India and in the Central Provinces the maximum prevalence of the disease occurs just at those periods when the soil-conditions most closely approach those in Calcutta when in its driest state, *viz.*, during and towards the end of the rains, at which period alone the soil-conditions of the former are approximate to those in Lower Bengal during the greater portion of the year. After bestowing the most careful consideration on this matter, and after endeavouring to examine it in all its phases, we have come to the conclusion that the theory which regards conditions of the soil as essentially determining the production of the cause of cholera in a locality, is much more in accordance with the phenomena of its seasonal prevalence as manifested throughout the Bengal presidency than any of the other doctrines appear to be.

CHAPTER III.

CONCLUSION.

In manifesting a marked partiality for a soil of the character of the Gangetic alluvium, cholera is by no means singular, for it is a well-established fact that malarious fevers and kindred diseases flourish with most vigour about the deltas of large rivers all over the world.

The connection between soil and malaria, as a connection implying cause and effect, is not seriously questioned, and the apparently capricious manner in which some districts evolve it and others do not, is a well-recognised fact: swampy and arid soils alike being capable of producing the miasm during certain seasons.

In this malaria presents a considerable resemblance to cholera, for, although both affections manifest a marked tendency to become endemic in alluvial districts, there exist, nevertheless, very numerous localities, even in tropical and subtropical climates, where both affections are unknown, such for example as the extensive swampy districts in South Australia. That cholera also is unknown there is commonly attributed to the circumstance that India is too far removed to allow of the transport of infectious material, but no one has yet attempted to explain the absence of malaria on such grounds.

We would not, however, be understood to imply that the causes productive of malarious fevers and cholera are identical, or that localities providing the conditions necessary for the development of the one must, therefore, provide those for the other also.

There are malarious localities of the most pronounced type where cholera has never flourished, notwithstanding that cases of the affection have been brought there, and fatal cases too. Of these, probably no better example could be cited than the large convict settlement at the Andaman Islands, where cholera has never thriven, notwithstanding the fact that it is within 3 days of India and 24 to 36 hours of Burma, and that during the last twenty years steamers have constantly passed between the two countries and the settlement. A steamer laden with convicts proceeds to Port Blair (the only port in the islands) from Calcutta every four weeks, and cholera cases have on some occasions been imported and have died after landing; but it is only on rare occasions that cases of cholera have been registered as occurring in any part of the settlement.

Dr. Rean, the late Principal Medical Officer to the Settlement, however, in his annual report for 1870 (quoted by Dr. C. Macnamara, *op. cit.*, page 336), describes cases of the following character:—

"The patients were generally admitted from some feverish locality, or had been employed on works of an unhealthy character. They were taken ill somewhat suddenly, the most urgent symptoms being frequent purging and vomiting with great prostration. The alvine evacuations bear a resemblance to curds mixed with bloody serum, and the

vomited matters were a light-coloured watery fluid; the countenance pinched, voice hoarse and husky, tongue pale, and breath cold, the extremities of the fingers and toes puckered, pulse not perceptible, and the surface of the body cold and clammy. The patients suffered from cramps of the stomach and extremities, and had great thirst; respiration was much restrained, causing extreme anxiety and a presentiment of approaching death; in most cases the urinary secretion was suspended. The only diagnostic sign to distinguish the disease from cholera was the character of the stools, and they sometimes approached the conjee-like character of choleraic evacuations."

During a visit to the Andamans in 1872 one of us had an opportunity of witnessing a case of this kind. In this instance the rice or conjee-water character of the evacuations was very evident, together with every other characteristic symptom of cholera, including suppression of urine. Dr. King, the Surgeon-Major in charge of the hospital, had witnessed several such cases, but had hesitated to return them, whether fatal or otherwise, as cholera, because there was no general diffusion of the disease among the convicts.

The importance of well-authenticated records of cases of this character can scarcely be overrated in connection with the etiology of cholera. Questions of possible contagion or of water-contamination by a specific material can hardly be seriously entertained here; there can be no casual importation of cases among an isolated community of this character, as the recent history of every person landed is accurately known. Somewhat similar cases habitually occur in every city in India, as well as every summer in nearly all the large cities of Europe. These, however, excite no special comment unless an epidemic breaks out in any part of the country; on this the previously ignored cases are carefully collated and described as the starting points of the pestilence: it is not the custom to look upon such cases *then* as due to a localised generation of the disease.

That, in the present state of our knowledge of the subject, it may appear difficult or impossible to explain all the phenomena of the distribution of cholera by coincident conditions of the soil must be at once allowed. But at the same time, when we come to inquire into the point, we find that just as many difficulties present themselves in reference to malarial affections.* Whilst generally associated with moisture of air and soil, they also occur in certain localities which might have been regarded as quite incapable of furnishing the conditions for their production. In some of these cases,

* "Malaria sometimes breaks loose from its endemic haunts and shows itself in places where it has seldom or never before appeared. It thus loses its endemic character and sweeps over considerable regions of country as an epidemic or over vast sections of the globe as a pandemic. . . . In view of what has been said before, it does not seem probable that currents of air are capable of carrying the poison which is generated in the breeding places of epidemic to a distance of any considerable number of miles. We believe rather that malarial poison is, in the majority of cases, generated on the spot. . . . It is a still more difficult matter to account for those isolated areas of malarial poison which are often confined to a single street, or to one side of a street, or even to single houses, unless, indeed, supposing them to arise from subterranean swamps and collections of waters, the exhalations from which reach the surface through rifts in the ground."—H. Hertz on "Malarial Diseases" in Ziemssen's *Cyclopædia of Medicine*, 1875, p. 578.

such as the oases in the Sahara, the unfitness may be only apparent, and, on closer inquiry, conditions may be demonstrated calculated to produce the result. In others, however, no satisfactory explanation can be afforded. The telluric origin of the cause producing the symptoms of malarial poisoning is not, however, on this account doubted, and if this be so there is no sufficient reason for doubting the telluric origin of the cause of cholera in similar exceptional cases.*

Not only do we observe marked parallelism between cholera and malaria in the capriciousness manifested by the apparently very opposite conditions of soil in which the diseases are sometimes observed, but also in the manner of their diffusion. It is a matter of common experience that removal from a locality in which cholera exists is a remedy against the spreading of the disease, and the Government of this country has, for many years past, acted on this knowledge with regard to its troops and prisoners with the greatest benefit. It is equally a matter of experience to find the population of one part of a district suffering severely from fever, whereas others are practically exempt, without any very evident difference in the localities being observable; and just as in the case of an outbreak of cholera, how often has it not been observed that crossing to the other side of a river or shifting a ship a few hundred yards from where it had been at anchor, has sufficed to put an end to a regular epidemic of malarious affections? With regard to both affections tracts of country which suffer in one season are exempted in the next, whilst districts formerly exempted are in their turn attacked: at the same time, the two diseases manifest a decided predilection to attack some localities at all seasons.

It is not uncommon to find that cholera is described as passing over large tracts of country, either with the wind or in its teeth, according to the particular views entertained by the writer, leaving the impression on the mind of the reader that some pernicious influence had passed over the land. But is it not a fact that cholera, instead of spreading itself over the country on any systematic, geographical plan, often appears simultaneously in districts perhaps a thousand miles apart? Does it not seem more reasonable to infer that the disease was generated at or near the place of its occurrence in the same manner as outbursts of malarious fevers?

There is nothing more remarkable in the production of an attack of cholera than in the production of an attack of ague; in some respects, indeed, the latter is the more remarkable of the two, seeing that once acquired the symptoms may recur

* "No chemist has yet been able to demonstrate the existence of malaria. We assume its existence from certain observed effects on the organism just as we do in the case of other poisons which produce certain specific diseases. Malaria is believed to be the product of organic decomposition in soils, whatever may be their mineral composition; water is indispensable to the process, and a high temperature, although not absolutely necessary, greatly aids it. . . . It is often found in sandy soils and arid-looking plains, devoid of vegetation; but in all such cases the soil will be found to contain a considerable portion of organic matter, and water will be found not far from the surface, either in the shape of subterraneous streams, or detained by a bed of clay below the sand. . . . Malaria is also generated in hard rocks such as granite and trap, in a disintegrating state. A notable example is the island of Hongkong, which consists entirely of weathered and decaying granite."—W. C. Maclean on "Malarial Fevers" in Reynolds' *System of Medicine*, 2nd Edit., Vol. I., p. 591.

at long periods after the original attack and without subsequent exposure to the influences that originally produced it. It is true that although malarious fevers are not so appallingly fatal as cholera, nevertheless it has not been always so. During periods when cholera was either unknown in Europe or a far milder form alone of it prevailed, malarial fevers almost depopulated whole tracts of country—many parts of England suffered terribly, and Sir Gilbert Blane states that the mortality in London from ague during 1558 was so great that the living could not bury the dead.

We would not for a moment have it supposed that we consider the two affections as mere gradations of the same disease; all that we desire to urge is that cholera has as good a claim as malarial diseases to a telluric origin. What the essential cause may be remains unknown in both cases; but the fact that the production of malaria is so greatly under the control of improvements in local conditions warrants us in looking confidently to similar results with regard to the cause of cholera also.

CALCUTTA,
December 1877.

TABLES I TO VII:

A Summary of the Registers of Observations on Water-level, &c., taken in the Bengal Presidency during 1870-76.

[THE STATIONS ARE ARRANGED IN ALPHABETICAL ORDER.]

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE I. **1870.**

Numbers.	STATION.	Elevation above Sea-level [in feet.]	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level [in feet].†	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.
1	Agra (Civil) ...	555	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
2	,, (Military) ...	...	54·5	0	0	55·0	?	0	55·5	0·5	0	56·0	0	0	56·7	0	0	?	?	2
3	Allahabad (Civil) ...	306	...	...	...	...	...	..	...	...	...	...	...	...	...	...	..	...	...	...
4	,, (Military) ...	...	49·8	?	5	50·9	?	24	51·3	0·9	3	52·0	0·7	4	52·6	0	6	53·0	4·4	5
5	Amritsar ...	756	22·0	0	0	22·3	0	0	22·5	1·6	0	22·5	0·2	0	22·3	0	0	23·0	0·7	0
6	Azimgurh ...	756	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...
7	Bareilly ...	568	8·3	?	0	8·2	?	0	7·2	?	0	6·6	?	0	?	?	0	...	...	...
8	Barrackpore ...	20	6·9	0·5	?	8·1	?	0	...	...	...	...	...	...	?	1·4	5	...	...	...
9	Benares (Civil) ...	267	36·7	0	0	36·6	0·3	0	37·5	0·3	64	38·2	1·5	213	28·4	6·7	34	?	4·8	numer-ous.
10	,, (Military) ...	...	40·4	...	...	40·9	...	...	40·1	...	...	41·0	...	...	44·9	...	...	44·7	...	...
11	Berhampore ...	65	7·4	0	0	8·2	?	0	9·9	?	?	11·0	?	?	11·9	1·8	?	12·8	11·4	1
12	Calcutta (Alipore) ...	16		...	...	...	...	...	...	...	...	14·8	4·0	382	14·9	0·9	165	14·5	16·0	118
13	,, (Fort William)	18	10·0	0·7	171	11·4	0	259	12·6	0·3	257	12·9	...	...	13·4	...	...	13·9	...	...
14	Cawnpore ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	Chindwarra* ...	...	14·9	0	0	18·5	0	0	22·6	3·4	0	23·9	1·3	0	24·9	0	0	26·8	12·9	0
16	Chyebassa ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
17	Delhi ...	717	34·4	0	0	34·1	0	0	35·3	2·3	0	35·4	0·8	1	35·9	0	0	36·1	6·2	?
18	Dinapore ...	189?	22·3	?	?	24·1	0	2	25·1	0·1	0	26·0	0·2	0	26·4	0·4	6	25·7	10·3	38
19	Dum-Dum ...	20	...	...	...	...	...	...	...	...	...	...	...	...	9·0	0·5	0	9·2	6·0	0
20	Ferozepore ...	...	33·1	0	0	32·5	0	0	32·2	1·4	0	32·2	0·3	3	32·0	0·3	0	32·1	1·4	0
21	Fort Attock ...	...	31·5	0·2	0	32·0	0·4	0	32·8	2·8	0	29·3	0·1	0	29·6	0	0	30·0	2·0	0
22	Fyzabad ...	400?	...	...	...	...	...	...	...	...	...	?	1·1	22	28·0	0·3	3	28·1	14·4	1
23	Goorgaon ...	...	15·9	0	0	14·9	0	0	13·7	2·1	0	13·3	0	0	11·6	1·5	0	9·4	3·3	0
24	Goruckpore ...	255	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
25	Gujranwalla ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	24·0	3·1	0
26	Gujrat ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	17·7	2·2	0
27	Hazaribagh ...	2,010	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28	Hissar ...	...	...	...	...	...	...	...	...	...	...	...	...	...	106·7	0	0	106·7	2·6	0
29	Hoshungabad ...	1,020	57·5	0·5	0	58·3	0·1	0	58·9	0·3	0	59·3	0	0	59·9	?	?	Well dry	7·1	0
30	Hughli (Chinsurah) ...	30	8·8	1·6	?	9·9	0	?	10·9	0	?	11·6	2·9	?	12·1	2·9	?	12·7	4·1	?
31	Jessore ...	20	12·1	0·2	?	12·6	0	0	13·0	0·2	0	13·4	6·0	0	13·6	7·6	0	14·0	16·3	?
32	Jhansie* ...	859	...	...	...	12·8	0	0	13·0	0·7	0	13·1	0	0	13·1	0	0	13·1	8·1	0
33	Jhelum ...	...	23·3	?	?	25·0	0·4	0	24·9	1·6	0	23·6	1·0	0	22·5	0	0	21·7	9·7	0
34	Jubbulpore (Civil) ...	1,351	6·6	0·6	0	9·6	0·2	0	12·0	1·4	0	14·6	0	0	18·9	0	1	21·8	14·1	0
35	,, (Military) ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
36	Jullundur ...	...	21·3	0	0	21·3	0	0	21·4	?	?	...	...	...	...	...	...	...	...	...

* Indicate that the Water-level returns have required correction

† Indicates distance of Water-level from surface of ground

PREVALENCE *in various Stations in Bengal for the year 1870.*

1870. **TABLE I.**

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.		
...	...	...	68·4	?	3	68·9	0·5	0	?	?	?	...	...	...	...	...	...	Dr. A. Christison	1
53·8	?	2	52·9	...	...	52·7	...	...	53·1	?	?	53·8	0	0	54·0	?	0	Drs. C. H. J. Godwin, E. White	2
...	...	...	...	...	...	62·0	7·8	0	57·0	9·3	0	56·8	0	0	56·9	0	0	Dr. J. Irving	3
50·6	16·5	2	45·0	16·8	0	43·5	...	...	44·3	10·2	...	46·6	...	...	47·2	..	...	Dr. J. C. Bow	4
22·1	1·2	0	22·0	4·1	0	21·7	5·0	0	21·7	0·4	0	21·6	0	0	21·6	0·5	0	Drs. J. Ferguson, A. Taylor ...	5
...	...	...	15·1	?	?	6·7	3·1	0	12·5	1·0	0	14·1	0	0	16·1	0	0	Dr. R Jameson	6
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. H. C. Guinness ...	7
15·0	9·7	1	13·9	9·9	0	7·4	5·7	0	7·5	2·5	0	7·9	4·3	0	?	?	?	Drs. Menzies, Verchere ...	8
?	?	?	?	?	?	28·4	6·7	31	29·0	7·0	14	31·9	0	2	34·0	0	0	Dr. R. Cockburn	9
43·3	31·3	8	?	...	...	?	...	...	37·0	...	...	37·1	...	...	38·9	...	...	Drs. Perkins, Fitzmaurice ...	10
European troops removed from station						...	...	...	...	...	...	...	...	...	...	...	...	Dr. E. R. O'Brien	11
13·0	10·9	50	10·0	11·2	40	7·9	9·0	30	10·5	3·9	37	10·5	1·6	22	12·0	0	32	Dr. S. Lynch	12
13·3	...	...	12·9	...	...	6·7	...	...	8·4	...	...	8·8	...	...	9·9	...	...	Dr. D. H. Daly	13
...	...	...	...	...	...	40·5	11·1	0	39·5	4·7	0	38·7	0	0	38·3	0	0	Dr. J. H. Loch	14
19·4	10·1	0	8·9	4·4	0	7·9	6·2	1	6·2	6·7	0	8·0	0	0	10·8	0	0	Mr. A. G. Price	15
2·8	10·7	?	1·7	11·0	?	0·0	8·2	?	0·0	5·7	?	0·0	...	...	?	1·2	?	S. A. Manook	16
34·4	2·8	?	33·1	11·5	?	32·7	0·5	?	32·7	0	?	33·9	0	?	34·6	0	?	Dr. J. V. Fishbourne ...	17
14·10	8·0	3	10·2	10·9	12	7·4	6·7	2	12·5	9·4	3	15·7	0	0	20·9	0	0	Drs. R. T. Wright, Carmichael	18
7·2	10·0	0	4·0	14·4	0	2·9	9·6	0	3·1	2·3	1	3·9	1·0	1	4·9	0	0	Capt. A. Walker	19
32·1	1·1	0	32·3	8·3	0	32·0	0·1	0	31·6	?	0	31·6	0	0	31·8	1·1	?	Dr. J. Davis	20
29·9	0·5	0	29·5	2·9	0	27·8	0·1	0	28·0	0	0	28·7	0	0	29·9	?	0	Drs. R. Adams, G. Andrew ...	21
26·1	29·7	0	24·6	14·4	0	24·6	13·7	0	24·9	3·2	0	...	...	...	?	?	?	Dr. A. B. Seaman	22
9·0	5·6	0	12·0	2·3	0	13·7	1·6	0	13·8	0	0	13·4	0	0	13·6	0·1	0	Dr. R. Willmot	23
...	...	...	...	...	...	11·0	8·3	0	8·2	3·1	0	9·3	0	0	16·1	0	0	Dr. C. Prentis	24
23·9	3·4	0	23·9	7·8	0	23·7	0	0	23·9	0·6	0	24·0	0	0	24·1	0	0	Dr. Bose	25
17·4	4·8	0	17·4	4·4	0	17·2	2·0	0	17·6	0	0	17·3	0	0	17·4	0	0	Dr. W. P. Dickson	26
20·0	9·4	196	4·5	20·2	50	0·9	7·7	0	1·5	6·5	0	0·9	?	?	?	?	?	Dr. W. H. Corbett	27
106·2	2·5	0	106·4	7·4	0	103·5	0·2	0	103·7	0	0	103·5	0	0	?	?	?	Dr. J. A. Cooper	28
58·7	10·2	0	55·8	9·2	0	55·0	5·1	0	54·9	2·9	0	55·6	0·1	0	56·9	0	0	Dr. P. Cullen	29
11·6	6·8	?	3·7	9·2	?	2·6	10·2	?	4·0	2·7	?	5·3	1·4	?	6·9	0	?	Drs. T. Best, G. E. Dobson ...	30
11·3	13·0	0	8·9	17·0	0	7·2	8·3	0	6·5	7·0	0	8·0	0	0	10·5	0	0	Dr. D. P. Shipton... ..	31
12·3	7·5	0	11·0	13·8	0	10·2	8·3	1	10·6	0·7	0	11·8	0	0	11·9	0	0	Dr. H. W. Spry	32
22·7	14·8	0	21·9	15·6	0	21·9	3·1	0	21·8	0	0	22·2	0	0	22·7	0·9	0	Drs. E. Gardner, J. Clarke ...	33
10·5	27·3	0	2·3	21·1	?	2·7	14·0	0	3·8	5·3	0	4·2	0	0	4·6	0	0	Dr. W. R. Rice	34
12·2	...	...	11·3	...	...	11·0	...	...	?	...	...	?	...	...	...	...	...	Drs. W. Eames, A. Duke ...	35
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. J. H. Oliver	36

owing to the apparatus having been read in the inverse way, &c.
throughout.

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE I. 1870.

Number.	STATION.	Elevation above Sea-level [in feet.]	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level (in feet).‡	Rainfall (in inches.)	Cholera.	Distance of Water-level (in feet.)	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet.]	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.
37	Kheree ...	...	...	...	...	...	...	...	...	...	...	30·6	0·5	0	30·9	0·2	0	30·8	12·0	0
38	Kurnal ...	...	24·8	0	0	24·9	0·4	0	25·1	3·5	0	25·0	0·8	0	24·7	0·8	0	25·1	3·0	...
39	Lucknow (Observatory)	369	...	...	...	...	...	...	...	...	...	15·8	0·7	0	16·2	0·2	1	17·2	9·9	0
40	,, (Central prison)	...	...	...	...	...	...	...	...	...	...	24·9	0·4	0	24·9	0·2	1	25·4	7·4	0
41	Ludiana ...	...	28·5	0·1	0	28·4	0·1	0	28·4	2·2	0	28·4	0·1	0	28·5	0·2	0	29·0	4·5	0
42	Lullutpore ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
43	Maldah ...	160	12·1	0·0	7	16·0	0	2	18·0	0·2	1	20·0	0·7	35	23·9	0·8	127	23·2	10·8	58
44	Mean Meer ...	...	37·0	0	0	36·9	0	0	36·9	0·2	0	36·9	0	0	36·8	0	0	36·8	1·3	0
45	Meerut (Civil) ...	739	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
46	,, (Military) ...	...	10·6	0	0	10·9	0	0	10·9	1·9	1	10·9	0·6	1	11·0	0·6	1	11·0	14·1	0
47	Midnapore† ...	108	18·4	0·9	11	21·0	0	10	22·3	0·5	0	22·9	0·3	0	23·6	2·3	0	20·9	10·5	0
48	Monghyr ...	160	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
49	Motiharee ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
50	Mozufferpore ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
51	Mundla ...	...	31·5	0·7	0	32·4	1·7	0	32·9	1·2	0	33·3	0·6	0	33·8	0	0	34·9	8·9	0
52	Murshidabad ...	...	7·8	0	0	8·5	0	?	9·3	0·4	?	11·0	1·1	?	11·9	2·9	?	12·8	11·2	?
53	Muttra* ...	550?	32·8	0	0	32·8	0	0	33·0	2·5	0	33·0	1·1	0	33·5	0	0	33·0	5·2	0
54	Nagode ...	...	...	...	...	8·5	?	0	10·0	0·7	0	11·8	1·2	0	13·6	0	0	15·2	4·7	0
55	Nowgong ...	...	...	...	...	...	...	...	...	...	...	22·9	0·2	?	23·0	0	0	23·9	3·5	0
56	Nowshera ...	...	38·0	0·5	0	38·2	0	0	38·4	1·6	0	?	?	?	...	...	...	...	...	...
57	Pertabgurh ...	...	...	...	...	...	...	...	...	...	...	23·5	0·6	0	24·1	0·7	1	25·6	5·4	0
58	Peshawur ...	1,165	...	...	...	...	...	...	...	...	...	...	...	...	81·7	0·9	0	82·3	0	0
59	Raipur ...	950	16·8	1·0	0	18·4	0	0	20·6	1·3	0	22·0	0·7	0	24·2	0·4	0	27·4	13·2	0
60	Rawulpindee ...	1,650	106·0	0	0	106·3	0·6	0	106·4	4·0	0	?	?	?	...	...	...	...	...	...
61	Roorkee ...	883	31·8	0	0	31·7	2·0	...	31·7	2·0	0	31·8	0·9	0	31·9	0	0	32·2	4·9	0
62	Saugor (Civil) ...	1,763	4·9	0	0	5·4	0	0	6·1	1·2	0	7·8	0·2	0	12·0	0	0	17·6	7·8	0
63	,, (Military)* ...	...	15·5	...	...	16·5	...	...	17·5	...	...	18·0	...	...	20·0	...	...	21·5	...	...
64	Seonee, No. 1 well ...	2,030	8·8	1·3	0	11·3	0	0	13·0	1·6	0	15·0	0·2	0	17·2	0	0	17·9	16·3	7
65	,, ,, 2 ,, ...	...	17·0	1·3	0	20·6	0	0	23·6	1·6	0	25·9	0·2	0	28·0	0	0	29·5	16·3	7
66	Seepree ...	...	..	...	...	...	...	...	...	...	...	5·7	0	0	5·7	0·5	0	5·7	2·7	0
67	Seetapore ...	...	...	...	...	29·8	...	...	29·9	?	0	30·0	?	0	30·9	?	?	30·4	?	0
68	Sialkote* ...	829	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
69	Sirsa ...	...	...	...	...	104·3	0	0	102·9	1·8	0	102·7	0·5	0	102·7	0·2	0	102·9	4·9	0
70	Subathoo ...	5,000?	...	...	...	8·4	1·6	0	8·3	4·0	0	8·2	0·1	0	8·2	?	0	8·3	12·6	0
71	Sylhet ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
72	Umballa ...	902	26·8	0	0	26·8	0·2	0	26·4	2·6	0	26·2	0·8	0	26·1	0	0	26·1	7·1	0

* Indicate that the Water-level returns have required correction

† Rainfall in the district during previous year between 20 and

‡ Indicates distance of Water-level from surface of ground

PREVALENCE *in various Stations in Bengal for the year 1870*—continued.

1870. TABLE I.

July.			August.			September.			October.			November.			December.			WATER-LEVEL OBSERVATIONS RECORDED BY	Number.
Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera.		
28·1	13·6	0	26·8	13·3	0	21·3	8·3	0	21·0	0·4	0	20·4	0	0	20·9	0	0	Dr. W. W. Galloway ...	37
25·2	4·2	0	24·1	4·8	0	24·1	4·0	0	24·5	0	0	23·9	0	0	23·9	0·8	0	Drs. Lethbridge, Metcalfe ...	38
15·5	15·7	0	11·0	20·1	1	6·5	17·1	0	7·6	2·44	0	8·8	0	0	9·9	0	0	Dr. C. Cameron	39
24·3	13·0	0	23·8	20·8	1	19·2	?	0	17·3	4·0	0	17·4	0	0	18·1	0	0	Dr. C. Cameron	40
28·8	4·4	0	27·3	7·5	0	25·2	3·2	0	24·0	0·1	0	24·1	0	0	24·0	0·8	0	Dr. Ince	41
...	...	...	...	...	...	2·9	?	0	3·4	?	0	3·0	?	0	3·7	?	?	Dr. F. W. Sanders	42
14·9	13·2	14	8·7	11·6	0	4·3	8·9	1	5·8	7·1	0	5·7	0	2	7·7	0	2	Civil Surgeon	43
36·8	3·6	0	36·8	7·9	0	36·8	0·1	0	?	?	?	?	?	?	36·7	?	?	Drs. Mantell, Birch ...	44
...	...	...	...	...	...	12·8	4·0	0	13·6	0	0	13·3	0	0	13·7	0	0	Dr. W. Moir	45
10·4	11·7	0	9·8	6·9	1	9·0	4·7	0	8·9	0	0	9·0	0	0	9·3	0·3	0	Drs. Fogo, Clapp	46
10·0	12·5	3	5·6	14·0	0	3·9	5·5	0	6·8	5·5	0	?	?	?	...	...	...	Dr. R. G. Mathew... ...	47
...	...	...	...	...	...	...	...	...	36·9	8·4	?	38·8	0	?	?	?	?	Dr. O'C. Raye	48
...	...	...	...	...	...	4·6	4·6	0	6·9	11·2	0	6·2	0	0	7·3	1·2	0	Dr. J. Cullen	49
...	...	...	12·8	?	?	6·7	14·4	0	8·0	14·0	0	7·0	0	0	11·9	0	0	Dr. E. J. Gayer	50
33·0	15·1	0	27·5	13·6	0	26·6	6·9	...	28·3	1·8	0	29·5	0	0	31·0	0	0	Dr. H. A. Kidd	51
9·7	9·6	?	7·0	10·0	?	6·0	13·5	?	4·4	4·5	?	4·6	0	?	5·4	0	?	Dr. J. White	52
33·1	10·5	0	33·3	7·8	1	33·6	4·0	0	34·0	0	0	33·9	1·5	0	34·0	0	0	Dr. G. Pain	53
15·2	12·0	0	7·8	30·0	0	0·4	6·3	0	1·8	13·3	0	2·4	0	0	2·6	0	0	Captain E. J. V. Holloway ...	54
23·2	4·7	0	21·9	7·5	0	20·9	4·6	0	20	?	?	20·3	...	...	22·9	0	0	Dr. J. E. Fannin	55
36·7	?	?	36·9	8·3	0	36·8	0	0	36·8	0	0	37·0	0	0	37·3	2	0	Dr. G. Griffith	56
24·2	27·0	0	22·7	13·7	0	20·9	8·8	0	20·0	0·6	...	19·3	0	0	21·0	0	0	Dr. J. Hart	57
82·5	0	0	83·0	3·2	0	83·3	0·6	0	83·6	0	0	83·8	0	0	83·9	0	0	?	58
10·4	18·2	0	5·2	13·8	0	4·8	11·0	...	9·7	2·5	0	11·9	3·6	0	14·9	0	0	Dr. D. W. Trimnell ...	59
...	...	...	...	...	...	...	...	...	106·4	?	0	106·3	0	0	106·4	0·8	0	Drs. Jameson, Fitzgerald ...	60
32·0	14·6	0	31·6	12·5	0	31·0	6·3	0	30·6	0·7	0	30·4	0	0	30·2	0	0	Dr. A. Eteson	61
2·7	20·0	0	2·9	12·3	0	2·9	7·9	0	3·1	3·1	0	3·3	0	0	3·6	0	0	Dr. W. Williamson ...	62
20·8	...	...	11·9	...	...	9·6	...	...	7·0	...	...	8	...	...	9·8	...	...	Dr. G. F. Trimnell ...	63
1·9	23·3	0	1·9	6·2	0	1·9	5·4	0	4·5	4·0	0	4·6	1·7	0	8·5	0	0	Dr. J. Barter	64
11·2	23·3	0	7·5	6·2	0	7·6	5·4	0	10·0	4·0	0	10·0	1·7	9	13·9	0	0	Dr. J. Barter	65
5·7	6·1	...	5·7	7·8	0	5·7	3·0	0	5·7	3·2	0	?	?	?	?	?	?	Drs. J. Supple, G. Corry ...	66
30·7	?	0	30·7	?	0	28·1	?	0	28·4	?	0	27·1	?	0	27·8	?	0	Capt. Beadon, Dr. Townsend...	67
...	...	...	...	...	...	40·0	?	0	40·1	?	0	40·2	0	0	40·3	?	0	Drs. Malcolm, Brown ...	68
102·8	0	0	102·8	2·2	0	102·5	1·1	0	102·7	0	0	102·8	0	0	102·3	0·2	0	Mr. T. Nulty, Mr. J. Rehill ...	69
7·3	8·7	0	7·0	11·3	0	6·9	7·8	0	7·6	0·6	0	7·9	0	0	7·9	?	0	Dr. Roe, Ensign G. Griffiths...	70
...	...	...	...	...	...	...	...	...	2·4	8·0	0	3·1	0·1	...	4·0	0	0	Dr. R. Deacon	71
26·2	4·6	0	26·3	7·7	0	26·3	4·2	0	26·2	0·4	0	26·5	0	0	26·0	1·5	0	Drs. Macnamara, Macmullen	72

owing to the apparatus having been read in the inverse way, &c.
30 inches below the average amount.
throughout.

A Monthly Statement of WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE II. 1871

Number.	STATION.	Elevation above Sea-level [in feet].	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.
1	Agra (Civil) ...	555	66·6	1·5	0	66·7	0·2	0	66·4	0	0	66·0	0·4	1	65·9	2·4	1	65·9	5·3	3
2	,, (Military) ...	...	54·0	...	...	54·0	...	...	54·1	...	...	54·2	...	...	54·2	...	...	54·0	...	...
3	Akolah ...	923	29·6	0	0	29·7	0	0	30·0	0	0	30·6	0	0	31·3	0	0	31·9	?	24
4	Allahabad (Civil) ...	306	57·4	0·4	1	57·9	0·2	1	58·4	0	3	59·0	0	10	59·5	0·7	14	60·0	15·4	8
5	,, (Military) ...	...	47·9	...	...	48·7	...	...	49·0	...	...	50·2	...	...	51·2	...	...	51·1	...	...
6	Amritsar ...	750	21·5	0	0	21·7	2·9	1	20·7	0	0	20·9	0·3	0	20·8	1·3	0	?	5·7	0
7	Azimgurh ...	...	?	0	0	?	0·6	...	16·5	0	0	17·3	0·2	16	17·7	2·0	39	17·7	1·3	90
8	Beerbhoom ...	...	...	...	...	...	...	...	...	...	...	18·8	?	0	20·0	0·7	0	dry	3·5	0
9	Benares (Civil) ...	267	35·0	0	0	36·0	0	0	26·9	0·4	15	38·6	1·2	446	39·6	0·8	298	41·1	9·7	96
10	,, (Military) ...	...	38·5	...	...	39·0	...	...	40·1	...	...	40·6	...	...	42·6	...	...	43·7	...	...
11	Burdwan ...	102	...	...	...	...	...	...	...	...	...	...	...	...	13·3	4·0	7	13·8	8·0	4
12	Burisal ...	...	7·0	?	0	8·7	?	0	8·6	?	0	9·0	?	0	9·2	?	0	0·0	?	0
13	Calcutta (Alipore) ...	16	13·5	0	53	13·9	0·7	96	13·9	5·4	55	14·0	5·7	85	13·9	10·0	29	9·9	25·3	23
14	,, (Fort William)...	18	10·9	...	...	11·7	...	...	12·0	...	...	11·1	...	...	12·3	...	...	11·0	...	...
15	Cawnpore ...	...	38·1	0	0	37·9	0	0	37·7	0	0	38·7	0	2	39·4	1·1	?	39·9	8·2	20
16	Chindwarah ...	...	16·5	1·3	0	19·0	1·9	0	23·4	0	0	25·9	0	0	27·9	0·8	0	29·2	14·1	0
17	Chittagong ...	90	17·2	?	0	18·0	?	0	18·0	3·7	0	19·2	1·5	1	19·8	6·0	0	5·2	35·0	0
18	Comillah ...	717	5·0	0	0	5·8	0	0	6·0	2·3	0	6·6	4·8	0	5·6	18·5	4	2·7	22·8	18
19	Delhi ...	Appa	ratus	bro	ken	28·3	0	0	28·3	0	0	28·6	0·2	0	28·8	3·5	1	28·9	5·0	0
20	Deoghur ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
21	Dinapore ...	180	22·9	0	0	24·1	0	0	25·0	0·2	0	25·6	1·2	0	26·0	2·7	3	23·8	12·0	1
22	Dinagepore ...	...	10·1	?	15	10·9	1·0	13	11·1	3·1	14	11·9	2·1	33	12·8	12·5	51	12·8	12·3	8
23	Dum-Dum ...	20	5·6	0	0	6·2	1·6	0	5·5	6·4	0	6·1	3·8	0	6·1	8·4	0	3·8	14·0	1
24	Ferozepore ...	...	32·3	0	0	32·0	2·	0	32·8	0	0	32·7	0·7	0	32·8	0·8	0	33·0	5·1	0
25	Fort Attock ...	...	30·4	0	0	30·9	4·3	0	29·9	0·2	0	29·7	0·7	0	29·5	0·1	0	28·9	2·9	0
26	Fyzabad ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	New	well	18·0	10·8	0
27	Goalpara ...	386	...	...	...	...	...	...	...	...	...	...	...	...	22·0	21·0	3	16·9	16·5	8
28	Goorgaon ...	...	12·2	0·4	0	11·9	0·4	0	12·1	0	0	11·3	0·2	0	10·8	1·2	0	10·0	1·8	0
29	Goruckpore ...	255	10·9	0·2	0	11·4	0·4	0	11·9	0·1	0	12·6	0·1	0	13·3	5·7	0	13·9	7·4	0
30	Gujranwalla ...	...	24·2	0	0	24·4	1·2	0	24·5	0	0	24·7	0	0	24·9	0	0·8	24·9	3·7	0
31	Gujrat ...	...	17·2	0	0	17·3	2·6	0	17·6	0	0	17·6	0	1	17·8	0·6	0	17·4	11	0
32	Hissar ...	...	97·9	0	0	98·7	1·2	0	98·0	0	0	98·1	0	0	98·3	0·8	0	98·7	4·0	0
33	Hoshungabad ...	1,030	57·9	1·5	0	58·5	0	0	59·7	0	0	dry	0	0	dry	0·9	0	dry	14·2	0
34	Howrah ...	18	5·5	0	3	6·3	0·4	1	6·4	6·0	8	6·4	2·3	12	6·7	10·0	10	4·4	23·4	7
35	Hugli (Chinsurah) ...	30	8·2	0·5	5	9·1	?	6	9·9	3·1	17	10·0	4·0	9	10·6	9·5	4	7·9	15·9	3
36	Jhansie* ...	359	12·0	2·1	0	13·2	0·5	0	13·2	0	0	13·2	0·2	0	13·3	2·9	0	13·7	7·9	0
37	Jhelum ...	...	23·0	0	0	23·2	5·3	0	22·1	0·1	0	22·0	0·1	0	21·6	0·2	0	20·9	2·5	0
38	Jubbulpore (Civil) ...	1,351	4·9	0	0	5·9	0	0	6·9	0	0	7·9	0	0	9·5	7·1	0	9·5	7·1	0
39	,, (Military) ...	...	...	...	...	7·9	...	...	8·2	...	...	8·6	...	...	8·6	...	...	8·6	...	...

* Indicate that the Water-level returns have required correction owing to the

PREVALENCE *in various Stations in Bengal for the year 1871.*

1871. TABLE II.

July.			August.			September.			October.			November.			December.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.		
66·2	8·9	2	?	10·4	1	?	4·4	0	67·7	0	0	68·5	0	3	68·4	0·7	0	Drs. Christison, Pilcher	1
53·7	...	...	52·9	...	...	53·3	...	...	...	...	...	...	...	...	...	...	...	Dr. C. H. Y. Godwin ...	2
31·9	?	4	32·0	2·1	0	32·4	4·9	0	33·6	0	0	35·9	2·0	0	36·3	0	0	Drs. A. Porter, J. Pitts...	3
58·5	25·1	2	55·8	7·3	0	54·2	11·2	0	52·9	0	0	53·0	0	0	53·6	0	1	Dr. J. Irving ...	4
45·8	...	...	41·3	...	...	40·4	...	...	...	...	...	...	...	...	...	...	...	Dr. J. C. Bow ...	5
?	5·1	0	?	0	0	?	0·4	0	?	0	0	?	0	0	?	0	0	Dr. A. Taylor ...	6
17·2	7·8	18	14·8	4·7	3	14·0	9·0	4	?	?	17	?	?	49	?	?	9	Drs. E. Jameson, A. Wood.	7
14·9	8·3	15	8·4	17·3	13	?	?	?	...	...	...	...	...	...	...	...	...	?	8
35·0	12·9	35	28·4	11·2	154	23·9	10·7	38	25·5	0	0	27·3	0	0	29·6	0	3	Drs. Cockburn, Hooper	9
39·2	...	...	36·0	...	...	33·8	...	...	?	...	...	...	...	...	...	...	...	Drs. Perkins, Donnell...	10
9·9	13·5	3	4·9	16·7	4	3·5	11·9	1	4·0	5·4	0	5·0	0	0	6·0	0	0	Dr. Elliot ...	11
0·0	?	0	0·0	?	0	4·0	?	0	2·0	?	0	3·9	?	0	5·9	?	0	? Civil Surgeon ...	12
6·9	15·9	25	6·0	12·1	41	5·9	9·9	70	7·7	7·0	86	10·3	0	128	12·2	0	109	Dr. Lynch ...	13
4·9	...	...	4·9	...	...	4·7	...	...	...	...	...	...	...	...	...	...	...	Drs. Daly, R. T. Lyons...	14
38·6	15·8	0	37·3	7·5	0	36·8	5·1	0	36·5	0	0	36·7	0	0	37·1	1·6	0	Civil Surgeon ...	15
19·8	8·5	0	6·9	2·8	0	5·2	7·3	0	3·5	0	0	11·2	0·5	0	16·4	0·8	0	Dr. A. G. Price ...	16
2·2	16·5	0	5·2	16·7	0	4·5	7·7	0	6·9	8·4	0	9·5	0	0	12·1	0	28	Dr. Meadows ...	17
1·8	14·6	0	2·0	17·0	0	2·5	18·0	0	2·1	6·5	0	3·5	0	0	?	?	?	Dr. Stock ...	18
27·9	5·4	0	26·2	7·2	0	25·6	0·4	0	...	...	...	...	...	...	...	...	...	Drs. Candy, Hanrahan...	19
27·0	13·6	0	21·0	15·0	0	17·5	6·7	0	19·0	0·3	0	21·0	0	0	23·0	0·1	0	Civil Surgeon ...	20
14·1	10·9	0	7·7	13·4	3	7·0	18·3	0	4·0	...	...	...	...	...	...	...	...	Dr. J. C. Carmichael ...	21
10·0	15·8	22	9·6	12·7	26	7·9	6·2	25	6·9	0·2	15	8·9	0	49	10·0	0·1	71	?	22
2·1	12·0	0	2·1	5·5	0	1·3	9·7	0	...	...	...	...	...	...	...	...	...	Captain A. Walker ...	23
?	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. J. Davis ...	24
27·3	3·4	0	27·4	0·3	0	27·8	0·5	0	...	...	...	...	...	...	...	...	...	Drs. G. Andrew, E. White.	25
17·4	24·7	0	16·5	16·9	0	18·9	19·6	1	7·1	?	?	7·9	0	0	9·0	0·5	0	?	26
9·0	14·2	35	5·2	12·7	6	3·0	10·7	0	6·1	0·8	0	11·9	1·3	3	15·4	0	1	Dr. Briscoe ...	27
9·5	8·1	0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. R. Wilmot ...	28
12·4	20·3	0	9·7	21·0	0	2·9	19·0	0	2·3	0	0	6·4	0	0	9·0	0	0	Dr. C. Frentis ...	29
24·9	3·3	0	24·9	1·7	0	25·0	0·6	0	25·0	0	0	25·0	0	0	25·0	0·7	0	Dr. R. C. Bose ...	30
?	4·5	0	15·1	0	0	15·8	0	0	14·4	0	0	14·8	0	0	14·4	0·4	0	Drs. Dickson, Quinnell	31
98·8	2·2	0	99·0	0	0	99·3	1·6	0	99·3	0	0	100·4	0	0	100·4	1·0	0	Dr. J. Cooper ...	32
52·0	15·4	0	51·1	12·8	0	46·5	22·0	0	46·9	0	0	50·3	0·2	0	53·6	0	0	Dr. P. Cullen ...	33
1·8	17·0	7	3·9	12·5	12	5·3	11·4	17	2·4	6·4	47	1·0	0	67	1·4	0	121	Dr. R. Bird ...	34
2·5	13·7	5	1·3	19·2	4	1·7	7·7	36	4·3	4·6	550	4·3	0	2	6·2	0	63	Dr. R. F. Thompson ...	35
12·5	13·2	0	9·4	15·9	0	8·4	7·4	1	10·2	0	0	10·5	...	...	...	...	...	Dr. H. W. Spry ...	36
21·0	4·3	0	21·0	5·0	0	21·2	1·3	0	21·9	0	0	22·1	...	...	...	...	...	Drs. Gardner, Martin ...	37
10·6	?	0	4·4	?	0	2·2	13·1	0	3·5	0	0	4·9	0	0	7·0	0	0	Dr. W. R. Rice ...	38
7·5	...	0	2·0	?	...	0·0	...	0	...	...	...	...	...	...	...	...	...	Dr. G. Corry ...	39

registering apparatus having been read in the inverse way, &c.

A Monthly Statement of WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE II. **1871.**

Number.	STATION.	Elevation above Sea-level [in feet].	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet]	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.
40	Kheree ...	...	21·3	0·6	0	21·7	1·1	0	21·9	0	0	22·3	0·2	0	22·7	5·7	0	dry	9·8	0
41	Kishnaghur ...	...	...	...	...	...	...	...	...	...	...	...	...	...	3·6	8·0	0	2·7	12·0	0
42	Kurnal ...	...	24·6	0	0	23·9	4·3	0	23·0	0	0	24·0	0·2	1	24·8	1·2	0	25·6	7·4	0
43	Lucknow (Obsty.) ...	369	10·5	1·4	0	11·0	1·1	0	11·4	0	0	11·9	0	1	12·4	3·1	0	12·9	11·5	2
44	„ (Prison) ...	...	18·1	1·0	...	18·4	1·7	...	18·8	0	...	20·0	0	...	20·9	1·7	...	20·9	15·7	...
45	Ludianah ...	900	24·9	0	...	24·0	3·2	0	23·9	0	1	24·1	0·2	0	24·1	0·6	0	23·5	8·6	0
46	Lullutpore ...	...	4·3	?	0	4·6	?	0	4·8	?	0	4·4	?	0	5·1	?	0	6·9	13·7	0
47	Maldah ...	160	12·6	0	8	14·7	0·1	8	16·3	1·5	7	20·0	1·7	1	20·3	4·6	4	21·0	6·6	0
48	Mandla ...	...	32·0	0·2	0	32·1	0·5	0	32·7	0	0	35·3	0·1	0	35·5	1·3	0	36·0	12·1	0
49	Mecan Meer ...	...	36·7	0	0	36·6	0·2	0	36·6	0	0	36·6	0·2	0	36·5	2·9	0	36·5	1·9	0
50	Meerut (Civil) ...	739	13·6	0·8	0	13·6	2·2	1	13·5	0	0	13·9	1·0	0	14·2	3·7	0	14·2	6·8	?
51	„ (Military) ...	...	9·4	...	...	9·4	...	...	9·5	...	...	9·8	...	..	10·0	...	...	10·0	...	...
52	Midnapore ...	108	...	...	...	...	...	...	...	...	...	...	...	..	...	...	...	8·3	8·9	1
53	Monghyr ...	160	41·0	0	0	42·0	0·2	0	42·7	?	?	dry	1·2	0	dry	2·0	14	52·0	10·3	28
54	Motiharee ...	...	8·0	?	5	?	?	?	10·2	?	1	11·0	1·5	0	10·2	7·0	3	6·9	6·4	0
55	Mozufferpore ...	...	14·0	?	2	16·9	0·6	4	18·4	0	0	20·9	0·8	10	22·7	3·4	11	21·7	9·6	40
56	Murshidabad ...	...	6·1	0	0	6·9	0·2	0	7·7	1·3	0	5·7	0·1	0	9·7	7·3	0	9·0	13·0	0
57	Muttra* ...	...	33·9	0	0	33·9	0·7	0	34·0	0	0	34·2	0·5	0	34·3	0·4	0	33·7	8·7	0
58	Mymensing ...	...	...	...	...	7·1		0	7·5	0	0	8·7	?	0	12·7	?	0	6·4	?	0
59	Nagode ...	...	6·2	0	0	7·9	0	0	9·6	0	0	11·5	0	0	13·5	2·0	0	15·2	8·3	0
60	Nowgong ...	...	23·0	0·7	0	23·3	0·4	0	...	...	...	24·6	0·6	0	24·4	2·1	0	24·9	11·4	0
61	Nowshera ...	...	37·6	0	0	37·8	6·9	0	37·9	0	0	?	?	?	?	?	?	?	?	?
62	Oomraotee ...	1,206	23·9	0	0	24·5	0	0	25·1	0	0	26	0	0	28·0	0	0	28·3	0	0
63	Patna ...	179	...	...	...	...	...	...	...	...	...	...	..	...	...	...	...	7·0	?	?
64	Pertabgurh ...	...	...	...	...	...	...	...	New well			20·0	0	0	21·0	0·8	0	22·4	6·9	0
65	Purneah ...	125	1·9	0	0	2·4	0·3	4	3·0	0·4	0	3·4	3·4	1	3·8	3·1	0	4·0	14·2	0
66	Raipur ...	960	16·6	0	0	18·3	0	0	19·9	0·2	0	22·3	0·1	0	24·9	1·3	0	25·6	13·5	0
67	Rajshahi ...	...	7·9	?	0	9·3	0·1	0	10·3	0·9	0	12·9	0·3	0	15·1	5·6	0	13·5	15·2	0
68	Ranchi ...	...	13·8	?	?	14·4	0	1	14·7	2·1	4	15·8	0·3	7	16·9	3·4	1	5·9	16·6	7
69	Rawalpindi ...	1,650	106·4	0	0	106·0	6·4	0	105·9	?	?	...	...	...	...	...	...	...	...	...
70	Roorkee ...	886	30·0	1·0	0	29·9	3·1	0	29·7	0	0	29·7	0	0	...	...	...	...	...	...
71	Saugor (Civil) ...	1,765	5·5	1·2	0	7·3	6·4	0	9·0	0	0	11·7	0	0	14·7	1·1	0	15·1	14·6	0
72	„ (Military) ...	...	10·4	...	...	12·2	...	...	15·3	...	...	17·0	...	...	15·0	...	...	18·5	...	...
73	Seonee, No. 1 Well ...	...	11·0	0	0	13·7	0·4	0	16·0	0	0	18·3	0	0	17·0	1·4	0	17·2	15·6	0
74	„ „ 2 „ ..	2,030	17·3	...	...	19·9	...	...	22·6	...	...	25·6	...	...	23·2	...	..	31·2	...	...
75	Seetapore ...	...	27·4	?	0	27·2	0	0	27·1	0	0	27·2	0	0	27·8	3·6	0	27·9	?	0
76	Shajehanpore ...	...	20·9	0	0	20·9	?	0	21·2	?	0	21·3	?	0	22·4	5·6	0	22·9	10·5	0
77	Sialkote* ...	829	40·2	2·9	0	40·2	0·1	0	40·2	0·1	0	40·4	0	0	40·3	0·3	0	40·2	7·1	0
78	Sirsa ...	...	102·4	0	0	102·6	1·2	0	102·5	0	0	102·5	0	0	102·6	1·1	0	102·5	3·6	0
79	Sylhet ...	...	4·8	0	0	5·4	1·3	0	5·3	2·5	0	1·9	17·1	0	2·4	20·3	0	1·9	16·3	0
80	Umballa ...	...	25·7	?	?	24·9	1·8	0	25·6	0	0	25·4	0·2	0	24·9	2·4	0	25·0	11·6	0

* Indicate that the Water-level returns have required correction owing to the

PREVALENCE *in various Stations in Bengal for the year 1871*—(continued).

1871. TABLE II.

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.	Distance of Water-level [in feet].	Rainfall [in inches].	Cholera cases.		
27·4	23·0	0	25·8	11·5	0	22·8	11·3	0	22·6	0	0	23·9	0	0	?	0	0	Dr. J. Hart ...	40
Full	11·9	0	0·0	10·3	0	0·0	4·7	0	0·0	3·0	0	...	...	...	...	...	...	?	41
25·6	5·1	0	25·9	2·9	0	24·2	0·3	0	24·7	0	0	24·4	0	0	23·8	0·6	0	Drs. Metcalfe, Calthrop	42
10·9	20·9	0	8·1	5·3	0	6·7	24·1	0	6·9	0	4	8·3	0	420	9·3	2·1	373	Dr. J. Cameron ...	43
19·9	18·3	...	15·1	..	...	14·2	...	...	Well de	stroye	d by	heavy	rain	...	...	...	...	Dr. C. Cameron ...	44
21·9	0	0	21·4	2·0	0	21·1	0·7	0	20·9	0	0	20·9	0	0	20·7	0·7	0	Dr. J. Luce ...	45
?	12·3	0	4·2	13·4	0	4·2	6·2	0	3·7	0	0	3·0	0	0	4·9	0·3	0	Dr. F. W. Saunders ...	46
14·4	14·9	56	7·2	6·1	17	1·5	20·2	11	1·7	4·5	85	4·4	0	282	8·4	0	170	Dr. Chatterjee ...	47
34·9	25·0	0	26·3	2·3	0	28·8	8·2	0	28·6	0	0	30·8	0	0	31·6	1·4	0	Dr. H. A. Kidd ...	48
36·5	4·6	0	36·5	0	0	36·5	0	0	...	...	...	...	...	...	...	...	...	Drs. Poole, A. Deane ...	49
13·8	9·7	?	12·6	5·8	0	11·9	1·1	0	12·2	0	0	12·5	0	0	12·8	1·6	0	Dr. W. Moir ...	50
9·0	...	...	8·0	...	...	7·0	...	...	7·6	...	...	...	...	...	...	...	...	Drs. Clapp, A. Lewis ...	51
5·6	12·6	2	3·0	12·4	0	0·4	12·1	0	3·1	3·6	0	3·7	0	0	6·0	0	0	? Civil Surgeon ...	52
50·6	18·8	4	45·0	12·0	23	41·9	13·8	3	40·6	0	6	40·0	0	13	40·2	0	2	Dr. Mathew ...	53
5·6	12·4	0	6·1	?	?	5·6	25·6	1	1·9	2·0	7	4·0	0	0	4·6	0	0	? ,, ...	54
16·8	19·4	0	10·8	7·3	2	3·3	36·2	2	5·7	0·3	2	9·0	0·4	0	...	...	...	? ,, ...	55
6·9	14·5	0	3·5	12·14	0·9	?	?	1·1	1·8	0	2·9	...	...	...	4·6	0	1	? ,, ...	56
32·6	8·8	0	33·6	6·7	0	34·6	2·6	0	...	...	....	...	...	...	...	...	...	Drs. G. Pain, C. Smith..	57
5·9	?	0	6·2	?	0	5·6	?	0	3·0	?	0	5·0	?	0	6·0	?	0	? ...	58
13·0	25·5	0	1·0	13·0	0	0·0	18·2	0	...	...	...	...	...	...	...	...	...	Captain F. B. Boone ...	59
24·0	13·1	0	21·7	18·3	0	...	...	...	...	...	...	...	...	...	...	...	...	Drs. Ffolliott, Macnamara.	60
39·0	0·3	0	38·9	0·5	0	38·9	2·0	0	...	...	...	...	...	...	...	...	...	Drs. Griffith, Strachan	61
24·7	7·4	0	21·6	1·5	0	18·6	7·7	0	21·3	0	0	19·9	0·7	0	23·0	0·3	0	Dr. J. S. Howard ...	62
4·4	?	?	0·3	?	?	0·2	?	2	?	?	?	...	...	...	...	...	...	? Civil Surgeon ...	63
21·5	30·0	0	19·0	6·8	0	18·9	18·6	0	16·1	0	0	?	0	2	...	...	...	Dr. Hart ...	64
3·1	17·5	0	0·8	19·2	0	6·0	18·5	2	0·8	0·2	11	2·5	0	5	3·7	0	43	Dr. Picachy ...	65
10·3	15·4	0	6·2	3·3	0	7·1	12·7	0	10·4	0	0	16·2	0	0	18·8	0	0	Dr. D. W. Trimnell ...	66
6·6	22·2	0	2·6	15·7	0	2·0	10·4	0	2·8	1·6	0	5·0	0	0	6·6	0	0	Dr. Hoskins ...	67
6·5	11·8	43	4·6	14·2	33	4·0	13·3	11	7·2	0·3	6	8·7	0	3	13·2	0	3	Dr. Wood ..	68
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. R. E. Fitzgerald ...	69
...	...	...	...	...	...	..	...	...	....	...	...	...	...	...	...	...	...	Dr. A. Eteson ...	70
1·0	24·1	0	1·3	15·0	0	1·8	11·3	0	2·9	0	0	3·9	0	0	4·7	0·5	0	Drs. Williamson, Cowan	71
14·7	...	...	9·5	...	...	8·9	...	...	8·4	...	...	...	...	...	...	...	...	Dr. G. F. Trimnell ...	72
2·8	11·8	0	2·7	5·6	0	1·9	7·3	0	3·5	0	0	8·2	1·5	0	13·5	1·1	0	Dr. J. Barter ...	73
16·0	...	...	6·9	...	...	6·3	...	...	7·6	...	...	12·9	...	...	20·0	...	...	,, ...	74
27·7	?	0	27·0	10·0	0	27·0	9·5	0	...	...	...	....	...	...	...	...	..	Drs. E. Townsend, A. Hall.	75
21·5	29·7	0	18·6	11·1	0	17·8	8·2	0	17·4	0	0	17·5	...	...	...	...	...	Drs. Harris, Kelsall ...	76
40·1	8·9	0	40·1	2·0	0	40·0	2·7	0	40·0	0	0	...	...	...	...	...	...	Drs. Cherry, Wood ...	77
102·4	0·9	0	102·5	0·5	0	102·7	0·8	0	102·7	0	0	102·8	0	0	102·5	0	0	Mr. J. Rehill ...	78
1·9	24·4	0	1·9	24·0	0	1·4	18·5	0	2·0	18·4	0	3·1	0	0	4·2	0	0	? ...	79
25·0	15·6	0	24·9	9·0	0	24·9	1·8	0	24·9	0	0	...	...	...	...	...	...	Drs. R. Berkeley, Scott...	80

registering apparatus having been read in the inverse way, &c.

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE III. 1872.

NUMBER.	STATION.	Elevation above sea-level [in feet].	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.
1	Agra ...	555	68·9	·5	0	69·0	·1	2	68·9	0	0	68·6	0	3	68·0	1·8	6	67·9	1·5	29
2	Akola ...	923	37·1	0	0	37·6	0	0	38·1	0	0	38·9	1·7	0	39·2	0	0	40·3	0	0
3	Allahabad ...	306	52·8	2·1	0	53·0	0·2	6	53·6	0	1	54·2	0	8	55·0	0·3	6	56·8	2·7	4
4	Amritsar ...	756	22·6	·6	0	21·8	·7	0	21·0	1·0	0	20·9	·4	0	20·8	·6	0	20·9	1·4	0
5	Benares ...	267	30·8	1·6	0	31·5	0·4	0	32·5	0	0	34·3	0	593	36·6	·3	189	37·9	5·0	404
6	Burdwan ...	102	...	...	...	...	...	...	...	...	...	...	...	...	13·3	5·8	7	13·8	10·3	4
7	Calcutta (Alipore)	16	13·3	0·2	80	13·9	2·8	81	14·1	0·2	64	14·5	1·8	70	14·7	1·9	66	14·8	9·4	55
8	Cawnpore * ...	...	36·4	·5	0	36·3	0	0	36·8	0	0	38·0	0·2	3	39·5	·5	178	40·9	2·5	44
9	Chindwara ...	...	20·9	0	0	24·2	0	0	26·3	0·7	0	28·4	0·6	0	29·6	·1	0	30·7	9·2	0
10	Chittagong ...	90	17·0	·4	0	16·8	1·1	0	18·2	0	0	19·6	5·1	...	18·0	4·9	0	16·5	10·8	0
11	Deoghur ...	...	24·3	0	0	25·4	2·3	0	26·2	0·1	0	26·9	0·3	0	28·5	1·3	0	28·9	2·9	0
12	Dinajpore ...	...	10·8	·9	0	11·1	·8	0	11·4	·1	0	11·8	0	0	12·8	4·0	0	13·0	14·0	0
13	Fyzabad ...	...	10·7	·1	0	11·3	·5	0	12·0	0	0	12·8	·3	15	13·7	?	2	14·9	4·4	1
14	Goruckpore ...	255	10·0	2·0	0	10·9	·5	0	11·5	·3	0	12·3	4	0	13·0	2·5	3	13·8	4·3	4
15	Gujranwalla ...	...	25·0	2·6	0	25·0	1·5	0	24·0	2·5	0	25·0	·3	0	25·0	·3	0	25·0	0	0
16	Gujrat ...	...	14·5	0	0	14·3	1·1	0	14·6	3·9	0	14·7	6·0	0	15·1	4·7	0	15·6	5·4	0
17	Hissar ...	...	Appar	atus	un	der re	pair	...	...	...	...	92·9	0·5	0	93·2	1·2	0	93·4	2·7	0
18	Hoshungabad ...	1,030	55·5	0	0	56·6	0	2	57·3	·1	0	58·1	·1	0	59·1	·1	0	...	...	...
19	Jubbulpore ...	1,351	7·8	2·7	0	...	...	...	7·7	·6	0	8·5	·6	0	9·5	0	0	10·5	5·4	0
20	Kheree ...	...	25·9	1·2	0	?	1·1	0	?	?	?	?	?	?	28·2	·4	0	28·8	3·0	0
21	Kurnal ...	...	23·1	2·9	0	23·1	·1	1	23·5	·6	0	23·8	0	1	23·9	·4	3	25·4	6·1	0
22	Lucknow (Observatory) ...	360	9·8	1·6	0	10·0	·5	0	10·8	0	1	11·1	·5	0	12·5	·6	2)	13·1	1·7	22
23	Lucknow (prison) ...	...	10·2	...	...	10·6	...	...	12·5	...	...	15·3	...	...	20·9	...	..	21·2	...	0
24	Ludiana ...	900	21·7	1·9	0	21·6	·2	0	22·1	·4	0	22·1	1·3	2	22·0	·3	0	22·0	4·2	0
25	Lullutpore ...	...	8·1	·3	0	7·4	0	0	6·4	0	0	7·9	·2	0	9·9	·1	0	11·5	1·2	0
26	Mandla ...	...	32·9	0	0	33·4	0	0	34·7	·1	0	35·1	·1	0	36·3	0	0	36·8	11·6	0
27	Meerut ...	739	12·3	·3	0	12·1	·1	0	12·1	0	0	12·6	·4	0	13·0	·2	0	13·4	3·1	...
28	Moorshedabad ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	Mymensing ...	...	7·0	0	0	7·9	·8	0	8·8	0	0	10·1	4·8	0	9.6	6·5	0	...	16·6	0
30	Oomraotee ...	1,206	26·0	0	0	27·1	0	0	28·8	·1	0	30·8	1·6	0	31·9	0	0	34·6	6·0	?
31	Pertabgurh ...	...	?	0	0	?	0	0	?	?	?	?	?	?	?	?	?	?	?	0
32	Raipur ...	960	20·8	0	0	22·9	0	0	25·0	·1	0	27·5	1·5	0	29·8	0	0	31·3	11·8	0
33	Rajshahye ...	...	7·7	0	0	8·6	2·3	0	9·9	0	0	11·6	1·9	0	14·0	2·7	2	14·9	6·7	0
34	Saugor ...	1,766	5·5	·1	0	6·4	·1	0	8·6	·1	0	12·0	1·3	0	16·1	0	0	20·3	3·4	0
35	Seonee (No. 1 well)	2,030	15·0	0	0	16·7	0	0	18·2	·2	0	19·7	0	0	20·8	·4	0	19·2	15·5	0
36	„ (No. 2 „)	...	21·6	...	...	23·9	...	...	26·4	...	...	32·9	...	...	37·8	...	...	42·9	...	...
37	Sirsa ...	...	102·5	1·2	0	102·6	0	0	102·8	·1	0	102·6	·1	0	102·8	·3	0	102·6	·2	0

* Indicate that the water-level returns have required correction

PREVALENCE *in various Stations in Bengal for the year 1872.*

1872. TABLE III.

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.		
68·0	5·0	83	68·3	8·5	71	68·9	4·6	5	68·9	0	1	68·6	0	0	68·5	0	0	Dr. A. Christison ...	1
37·2	13·3	0	32·9	3·6	0	...	...	...	16·1	7·1	0	19·0	0	0	23·0	·1	0	Dr. A. Porter ...	2
56·4	11·1	12	55·0	25·9	43	52·1	5·3	10	51·6	0	0	52·8	0	0	53·9	?	0	Dr. J. Jones ...	3
20·9	7·0	0	20·2	8·8	0	20·2	4·4	0	20·7	0	0	17·2	0	0	17·2	0	0	Dr. F. M. Mackenzie ...	4
35·0	11·9	188	33·4	9·6	176	28·3	4·0	151	30·0	0	74	34·7	0	38	38·0	0	21	Drs. Cockburn, Hooper	5
9·9	8·4	3	4·9	17·7	4	3·5	11·9	3	4·0	5·1	0	5·0	0	0	6·0	0	0	Dr. Elliot ...	6
14·0	5·5	71	12·5	11·5	79	10·6	8·4	61	10·8	8·9	86	11·7	0·2	181	13·0	·05	248	Dr. S Lynch ...	7
40·0	4·8	11	38·9	12·7	7	36·3	1·2	0	36·1	0	2	36·7	0	0	36·8	0	0	Drs. Condon, Cleghorn	8
29·1	11·4	0	16·8	10·9	0	3·9	10·3	0	5·4	0·6	0	8·5	0·8	0	12·6	0·5	0	Dr. A. G. Price ...	9
4·1	30·8	0	6·0	15·9	0	6·0	14·9	0	8·7	4·7	0	9·8	0	0	12·2	·7	0	Dr. Meadows ...	10
...	7·6	...	28·5	9·2	0	28·0	7·1	0	27·5	10·3	0	26·7	0	0	26·1	0	0	Dr. S. N. Sing ...	11
11·9	17·6	0	8·4	16·7	0	6·4	10·9	0	6·9	10·6	0	7·8	0	0	...	0	0	Dr. Webber ...	12
...	...	...	...	...	...	12·3	8·6	47	12·5	0	62	12·9	0	5	13·7	0	0	Civil Surgeon ...	13
12·7	23·2	0	8·4	16·1	0	3·0	15·0	0	5·3	0	0	7·9	0	2	9·4	0	0	Dr. Prentis ...	14
25·0	6·5	0	25·0	7·6	126	25·0	4·5	71	24·8	0	2	24·9	0	0	24·9	·2	0	Dr. R. C. Bose ...	15
14·4	8·3	0	·?	5·9	80	?	1·9	0	?	1·6	0	19·6	0	0	?	·4	0	Dr. R. C. Quinnell ...	16
23·4	12·2	0	93·1	9·3	2	93·0	·1	0	93·0	...	0	93·0	0	0	92·6	1·3	0	Dr. J. W. Cooper ...	17
...	12·6	0	55·9	14·1	59	50·9	7·7	0	51·9	1·5	0	53·0	0	0	55·4	·2	0	Dr. P. Cullen ...	18
5·0	28·6	35	1·0	21·9	10	2·2	5·7	0	2·5	1·4	0	4·4	0	0	5·0	·4	0	Dr. W. R. Rice ...	19
27·7	7·0	0	26·9	15·4	0	23·5	10·6	1	22·2	0	0	23·4	0	0	24·7	0	0	Civil Surgeon ...	20
22·4	8·8	24	22·6	1·7	40	22·5	2·5	0	22·8	0	0	22·9	0	0	22·6	·6	0	Dr. A. Calthrop ...	21
12·8	9·8	29	11·0	22·7	56	9·2	3·2	20	10·0	0	16	10·9	0	20	11·7	0	18	Dr. E. Bonavia ...	22
19·9	...	...	16·0	...	26	13·2	...	26	14·5	0	16	16·2	...	...	16·4	...	...	Dr. Cameron ...	23
21·5	14·6	0	20·1	10·3	295	20·2	4·0	27	20·6	...	...	20·8	0	0	20·6	·6	0	Dr. J. Ince ...	24
9·9	5·3	0	8·0	11·1	0	7·0	4·3	0	5·5	0	0	6·9	0	0	7·9	0	0	Dr. J. M. Saunders ...	25
32·5	18·1	0	27·7	17·3	0	25·1	9·1	0	25·0	0	0	28·8	0	0	30·4	1·7	0	Dr. H. A. Kidd ...	26
13·1	8·6	0	12·3	8·7	80	12·9	4·4	356	12·1	0	22	12·2	0	0	12·2	2·2	0	Dr. W. Moir ...	27
...	...	...	...	...	...	...	...	...	2·0	5·9	0	3·8	0	0	7·4	0	0	Dr. Coates ...	28
3·2	15·5	0	2·8	15·6	0	3·0	22·3	0	3·3	3·8	0	4·9	0	0	6·0	0	0	Dr. Cowen ...	29
27·9	13·8	0	19·8	3·7	0	19·0	7·9	0	18·9	1·2	0	21·2	0	0	22·3	0	0	Dr. J. S. Howard ...	30
...	14·3	0	...	12·0	...	...	3·8	0	...	...	...	...	...	...	...	...	...	? ...	31
3·9	17·5	0	4·9	12·4	0	5·4	7·0	0	5·8	3·1	0	13·6	0	0	16·0	·1	0	Dr. D. W. Trimuell ...	32
11·0	10·3	0	10·5	4·9	0	?	15·4	0	?	10·4	0	6·0	0	0	7·0	0	0	Civil Surgeon ...	33
7·7	20·1	0	1·2	13·0	?	...	...	...	3·1	0	0	4·1	0	0	4·8	0	0	Dr. W. Williamson ...	34
8·5	14·4	0	1·2	16·1	0	1·2	8·2	0	2·5	·9	0	7·5	0	0	10·7	0	0	Dr. J. Barter ...	35
39·0	,,	,,	15·0	,,	,,	6·6	,,	,,	6·4	,,	,,	13·8	,,	,,	20·0	,,	,,	Ditto ...	36
102·4	8·8	0	102·3	3·4	0	102·5	2·0	0	102·5	0	0	102·7	0	0	102·6	1·4	0	Dr. J. Rehill ...	37

owing to the apparatus having been read in the inverse way, &c.

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE IV. 1873.

NUMBER.	STATION.	Elevation above sea level (in feet.)	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level (in feet.)	Rainfall (in inches.)	Cholera cases.	Distance of Water-level (in feet.)	Rainfall (in inches.)	Cholera cases.	Distance of Water-level (in feet.)	Rainfall (in inches.)	Cholera cases.	Distance of Water-level (in feet.)	Rainfall (in inches.)	Cholera cases.	Distance of Water-level (in feet.)	Rainfall (in inches.)	Cholera cases.	Distance of Water-level (in feet.)	Rainfall (in inches.)	Cholera cases.
1	Akola	923	25·8	0	0	27·7	·3	0	28·9	0·1	0	29·9	0	0	31·0	·2	0	31·5	5·0	0
2	Allahabad ...	306	54·8	0·1	0	55·4	0·5	3	56·0	0·5	2	56·9	0	11	57·9	0	16	57·9	0	5
3	Amritsar ...	756	13·0	0·1	0	12·3	0	0	12·6	0·2	0	12·7	0	0	13·0	1·4	0	13·1	0	0
4	Arrah ...	191	13·1	·3	2	14·6	0	1	15·3	1·2	1	16·0	0	0	16·8	·7	14	17·4	1·9	127
5	Benares ...	262	39·0	0	8	40·0	0	33	41·1	0·2	46	42·1	0	257	...	...	...	...	...	...
6	Burdwan ...	102	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
7	Calcutta (Alipore)	16	13·9	0	133	14·5	0	189	14·7	1·1	221	14·9	1·8	163	15·0	3·7	153	15·0	4·3	99
8	Cawnpore* ...	...	36·9	0	0	36·9	0	0	36·9	1·2	0	37·9	...	0	39·2	1·1	0	40·9	0	0
9	Chindwara ...	...	17·0	0	0	20·6	·7	0	23·0	·4	0	26·1	0	0	28·3	1·1	0	28·6	7·6	0
10	Chittagong ...	90	14·6	·3	3	16·8	0	0	...	...	...	19·0	5·1	0	11·0	5·2	3	3·7	21·1	0
11	Commillah ...	...	3·3	0	11	4·0	·5	0	4·4	1·5	5	6·6	5·5	28	4·2	8·3	23	4·8	17·5	0
12	Dinajpore ...	...	10·6	0	129	11·5	·5	58	12·0	·2	56	12·1	·6	207	14·5	·3	56	13·6	18·2	0
13	Fyzabad* ...	...	14·6	0	0	15·4	0	6	16·0	·9	0	16·7	0	0	17·5	0	0	18·3	1·1	0
14	Goruckpore ...	255	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
15	Gujranwalla ...	...	25·0	·1	0	25·0	·1	0	25·0	·8	0	25·0	0	0	25·0	2·3	0	25·0	·1	0
16	Gujrat ...	...	19·9	1·0	0	20·5	0	0	21·3	·6	0	22·4	0	0	22·6	1·4	0	22·9	·1	0
17	Hissar ...	...	91·3	0	0	91·7	0	0	90·7	0	0	92·4	0	0	92·0	1·8	0	93·0	0	0
18	Hughli (Chinsura)	30	10·3	0	12	11·4	0	21	12·2	·9	15	12·6	2·3	22	12·8	4·5	...	9·6 ?	4·4	...
19	Hoshungabad ...	1,020	56·5	·6	0	57·10	0	0	59·0	0	0	Well	dry.	...	...	...	...	...	...	...
20	Jubbulpore ...	1,351	6·0	0	0	7·2	·4	0	8·0	2·4	0	8·7	0	0	·9·6	·7	0	10·6	3	0
21	Kurnal ...	...	22·7	·6	0	22·4	0	0	22·3	0	0	22·9	0	0	24·5	3·8	3	24·8	·1	1
22	Lucknow (observatory) ...	369	12·0	·2	1	12·1	·3	0	12·9	1·1	0	13·2	0	0	13·8	·9	1	14·5	·5	0
23	Lucknow (prison)	...	17·9	...	...	19·9	...	...	21·1	...	...	22·0	0	0	22·9	...	...	23·5	...	...
24	Ludianah ...	900	20·7	0	0	22·9	0	0	23·5	·8	0	26·2	0	0	23·4	2·3	0	23·8	·5	0
25	Lullutpore ...	...	8·10	·6	0	8·11	0	0	10·2	0	0	10·11	0	0	11·8	0	0	12·5	·9	0
26	Maldah ...	160	15·0	·4	20	16·5	0	102	19·2	·2	324	20·9	1·1	824	22·6	0	202	23·6	4·3	50
27	Mandla ...	...	31·8	0	0	32·5	·1	0	33·6	·7	0	34·8	0	0	35·3	1·2	0	35·4	6·3	0
28	Meerut ...	739	12·5	·4	0	12·6	0	0	12·8	·9	0	13·0	0	0	13·7	1·3	0	14·0	·2	0
29	Midnapore ...	108	5·7	1·1	110	7·3	0	2	9·8	·7	5	12·5	1·9	12	11·3	9·2	27	10·8	7·1	1
30	Mozufferpore ...	...	16·2	2·2	0	18·9	0	0	18·3	2·2	0	18·2	·6	4	19·9	0	0	19·9	4·0	12
31	Mymensing ...	...	6·9	·1	0	7·9	0	0	8·5	...	...	Well	dry.	...	...	...	...	..·.	...	...
32	Oomraotee ...	1,206	23·2	·1	0	23·8	·7	0	24·5	0	0	26·0	0	0	27·2	1·3	0	27·0	6·9	0
33	Pertabgurh ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
34	Purneah ...	125	4·1	·2	0	4·6	0	0	4·9	·8	69	5·3	2·5	617	5·8	·4	69	6·3	7·8	6
35	Raipur ...	900	17·5	0	0	19·2	0	0	21·0	1·4	0	23·1	0	0	26·1	1·9	0	24·9	5·3	0
36	Rajshahye ...	...	7·9	·4	15	9·3	·1	15	10·9	1·4	54	12·3	1·0	108	14·8	·2	68	17·0	6·9	19
37	Ranchi ...	...	12·9	0	0	15·0	0	1	15·9	2·5	5	17·6	·5	3	18·9	1·2	16	19·6	2·2	22
38	Saugor ...	1,766	5·7	1·0	0	6·2	0	0	7·10	·1	0	11·8	0	0	16·6	·2	0	21·9	1·1	0
39	Seonee (No. 1 well)	2,030	12·6	0	0	14·5	·9	0	16·1	1·1	0	17·9	·6	0	18·3	1·2	0	18·9	2·7	...
40	„ (No. 2 „)	...	26·0	...	...	31·5	...	...	36·6	...	...	40·1	...	...	40·3	...	...	40·0	...	0
41	Sirsa ...	...	102·4	...	0	102·1	0	0	101·9	0	0	101·9	0	0	162·2	0	0	102·5	1·3	0

* Indicate that the water-level returns have required correction

PREVALENCE *in various Stations in Bengal for the year 1873.*

1873. TABLE IV.

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.		
31·1	5·7	0	32·1	7·5	0	28·0	4·6	0	28·8	0	0	31·3	·5	0	32·4	0	0	Drs. Laing, Porter . .	1
58·3	16·4	0	55·7	7·2	23	54·0	7·9	19	52·9	0	0	53·9	0	0	54·9	0	0	Drs. J. Irving, J. Jones	2
13·2	3·8	0	12·4	7·9	0	12·2	4·6	0	12·1	0·5	0	12·2	0	0	12·4	0	0·8	Dr. F. M. Mackenzie ...	3
17·3	19·7	632	7·3	10·9	149	9·2	3·0	6	10·7	...	...	...	...	...	13·1	·1	0	Dr. J. H. Thornton ...	4
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Civil Surgeon ...	5
...	...	...	4·4	...	...	5·	...	?	6·0	?	?	7·2	?	?	8·3	?	?	Dr. J. G. French ...	6
14·5	14·7	59	11·6	10·2	31	10·1	5·8	26	11·9	2·4	24	13·0	0·1	28	14·0	·8	29	Dr. S. Lynch ...	7
?	12·9	0	?	12·0	2	?	4·6	0	?	0	0	?	0	0	?	0	0	Dr. J. H. Condon ...	8
26·6	6·4	0	26·3	3·9	...	24·9	11·1	0	16·6	0	0	15·7	·2	0	21·0	·4	0	Dr. A. G. Price ...	9
8·5	19·3	0	2·2	18·9	0	5·9	11·1	0	4·0	4·7	2	...	...	...	13·9	·7	6	Dr. Meadows ...	10
1·8	8·7	0	1·2	25·6	0	2·7	4·6	0	2·9	·7	1	...	...	...	2·7	·7	50	Dr. W. Cowan ...	11
13·4	8·2	2	12·6	12·6	0	12·2	2·0	0	12·7	0	1	...	...	...	14·0	·3	6	Civil Surgeon ...	12
20·9	12·8	0	?	22·0	0	?	4·7	0	?	0	0	?	0	0	?	0	0	Dr. Cameron ...	13
...	...	...	...	...	...	...	...	...	12·4	0	0	15·0	0	0	15·4	0	0	Dr. Prentis ...	14
24·9	3·7	0	24·5	10·5	0	24·4	5·4	0	24·2	7	0	24·5	0	0	24·7	0	0	Dr. R. C. Bose ...	15
23·4	3·0	0	22·9	15·1	0	22·2	·5	0	22·8	0	0	22·9	0	0	23·4	·1	0	Dr. R. C. Quinnell ...	16
92·1	5·1	0	91·6	2·3	0	91·6	1·3	0	91·4	·8	0	91·4	0	0	91·4	·2	0	Dr. J. H. Cooper ...	17
7·7	15·3	...	4·0	6·7	65	3·3	3·7	80	4·9	·6	71	6·6	·1	113	7·8	·7	117	Dr. Thompson ...	18
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. P. Cullen ...	19
7·4	16·8	0	2·3	12·9	1	1·6	14·2	4	3·7	0	2	5·0	0	0	6·0	0	0	Dr. W. R. Rice ...	20
24·8	17·2	0	23·9	5·7	0	24·0	4·8	0	22·4	0	0	22·8	0	0	22·0	0	0	Dr. H. Cookson ...	21
15·2	13·4	3	12·0	8·6	5	11·6	11·0	14	11·0	·0	33	12·2	0	56	13·0	0	6	Dr. E. Bonavia ...	22
22·9	...	...	...	...	..	21·5	...	...	21·6	...	33	21·1	...	...	21·9	...	...	Dr. Cameron ...	23
23·9	8·2	0	23·1	5·4	0	22·7	2·9	0	...	...	...	...	...	...	...	...	...	Dr. R. Rouse ...	24
11·4	21·7	0	8·3	19·1	0	3·1	17·7	0	2·7	0	0	4·7	0	0	7·1	0	0	Dr. F. W. Saunders ...	25
23·0	7·0	3	16·2	7·7	7	14·3	4·8	2	...	...	...	...	...	...	20·5	2	23	Dr. Chatterjee ...	26
33·6	19·7	0	28·9	12·4	0	28·0	8·1	0	30·4	0	0	31·3	0	0	32·8	1·5	0	Dr. H. A. Kidd ...	27
13·8	11·3	0	12·9	6·2	0	12·3	7·8	3	11·8	·9	0	11·9	0	0	12·3	·5	0	Dr. W. Moir ...	28
9·7	13·9	9	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Civil Surgeon ...	29
20·1	11·5	5	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Civil Surgeon ...	30
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Civil Surgeon ...	31
25·1	7·6	0	23·1	11·2	0	18·9	8·9	0	20·0	0	0	23·0	0	0	24·0	0	0	Dr. J. S. Howard ...	32
15·0	10·8	0	13·1	11·6	0	12·5	6·6	0	12·9	0	0	12·9	0	0	13·5	0	0	? ...	33
6·0	10·9	1	5·9	10·6	0	4·9	6·7	0	4·9	0	0	...	...	...	5·5	·3	0	Dr. J. Picachy ...	34
22·6	12·4	0	6·3	11·5	0	4·9	8·1	0	11·7	0	0	17·4	0	0	20·0	·1	0	Dr. D. W. Trinnell ...	35
16·3	6·7	3	12·5	11·2	...	10·1	3·1	1	9·8	·3	0	...	...	...	13·3	0	114	Civil Surgeon ...	36
...	17·5	95	3·3	12·9	124	3·2	12·2	36	6·8	·6	0	...	...	...	13·9	0	1	Dr. E. J. Hoskins ...	37
23·3	9·8	0	2·7	11·0	0	·9	17·7	0	3·1	0	0	5·2	0	0	5·7	0	0	Dr. A. F. Renton ...	38
18·9	11·6	0	13·4	7·8	0	3·9	14·4	0	4·0	0	0	8·5	0	0	12·4	1·0	0	Dr. J. Barter ...	39
37·4	...	...	32·9	...	...	14·0	...	...	12·9	...	...	17·0	...	...	23·0	...	...	" " ...	40
102·4	2·6	0	102·3	1·3	0	102·7	1·2	0	102·8	·5	0	102·8	0	0	102·5	·2	0	Dr. J. Rehill ...	41

owing to the apparatus having been read in the inverse way, &c.

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE V. **1874.**

NUMBER.	STATION.	Elevation above sea-level (in feet).	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.
1	Akola ...	923	33·6	0	0	33·8	0	0	33·9	0	0	33·7	0	0	32·4	0	0	33·3	12·4	0
2	Allahabad ...	306	55·6	0	0	56·0	0	2	...	0·5	...	57·1	0	2	58·3	0	1	58·8	6·6	0
3	Amritsar ...	756	12·3	0	0	12·2	0	0	12·3	0	0	12·6	0	0	12·8	0	0	12·9	0	0
4	Burdwan ...	102	9·2	?	?	9·1	?	?	10·0	?	?	10·8	?	?	11·9	?	?	12·8	?	?
5	Calcutta (Alipore)	16	14·8	·9	69	14·9	3·7	182	15·0	1·9	193	15·0	1·2	250	15·2	1·1	217	15·2	6·8	86
6	Cawnpore ...	...	?	0	0	38·4	0	0	...	0	0	...	0	0	39·4	0	0	38·7	5·3	0
7	Chindwara ...	...	24·5	0	0	26·4	·6	0	27·5	·4	0	29·5	0·4	0	31·9	·5	0	31·8	14·5	0
8	Fyzabad ...	...	22·4	0	0	23·0	0·8	0	23·1	0	0	23·2	0	0	Dry	0·3	0	Dry	20·7	0
9	Goruckpore ...	255	15·9	0	0	16·4	1·0	0	16·8	0·1	0	17·1	0	0	15·8	0	0	16·0	11·3	0
10	Gujranwalla ...	...	24·5	1·8	0	24·7	1·6	0	24·8	2·4	0	24·9	0·1	0	25·0	0·7	0	25·0	2·7	0
11	Gujrat ...	...	23·4	3	0	22·9	1·7	0	23·0	2·1	0	23·0	1·3	0	22·8	0	0	22·9	2·9	0
12	Hissar ...	...	91·5	0	0	91·5	0	0	91·7	3·9	0	91·7	0	0	91·8	0	0	91·8	1·3	0
13	Jubbulpore ...	1,351	6·8	·3	9	7·5	·1	0	8·6	0	0	10·0	0	0	10·6	·9	0	10·9	18·5	0
14	Kurnal ...	...	?	0	0	22·2	0·4	0	22·7	1·2	0	22·8	0	0	22·7	0·6	0	22·6	6·5	0
15	Lucknow (observatory).	360	13·5	0	0	13·9	0·2	1	14·4	0·1	1	14·8	0	1	15·4	0	1	16·2	12·1	1
16	Lucknow (prison)	...	22·1	...	...	21·6	...	1	21·9	...	...	22·4	...	1	23·0	...	...	23·7	...	...
17	Lullutpore ...	...	9·2	·1	0	10·9	0	0	12·8	0	0	13·3	0	0	14·6	·4	0	16·0	6	0
18	Mandla ...	...	33·0	·7	0	33·7	·8	0	34·0	0	0	34·9	0	0	35·8	2·2	0	35·7	23·6	0
19	Meerut ...	736	12·0	·2	0	11·9	·1	0	14·4	0	0	12·4	0	0	15·4	0	0	13·1	·8	
20	Oomrawtee ...	1,206	24·9	0	0	25·9	0	0	26·9	0	0	27·9	·6	0	29·1	·9	0	28·9	9·6	0
21	Pertabgurh ...	...	13·8	0	0	13·8	0	0	13·9	0	0	14·1	0	0	14·4	0	0	14·8	3·9	0
22	Raipur ...	960	22·1	1·4	0	24·0	0·4	0	26·3	0·4	0	29·1	0	0	31·5	·9	0	32·9	20·3	0
23	Saugor ...	1,766	5·9	1·0	0	6·4	0	0	8·1	0	0	11·2	0	0	15·0	1·3	0	17·2	15·6	0
24	Seonee (No. 1 well)	2,030	14·9	·2	0	18·4	0	0	19·2	0	0	...	0	0	...	·5	0	19·1	11·9	0
25	Ditto („ 2 do.)	...	26·6	...	...	30·9	...	...	33·4	...	...	38·4	...	...	41·5	...	...	39·8	...	...
26	Sirsa ...	...	102·7	0·8	0	102·3	0	0	102·6	2·7	0	102·3	0	0	101·9	0	0	101·9	0·5	0

PREVALENCE *in various Stations in Bengal for the year 1874.*

1874. **TABLE V.**

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches.	Cholera cases.		
32·0	16·7	0	29·2	5·7	0	29·5	6·8	0	29·3	0·2	0	31·9	0·5	0	33·9	0	0	Drs. A. Porter, Laing ...	1
58·2	12·9	0	55·4	8·9	0	57·1	8·5	0	54·9	0·2	0	53·5	0	0	53·3	0	0	Dr. J. Irving ...	2
12·8	0	0	12·6	0	0	12·8	0	0	12·9	0	0	13·0	0	0	12·9	0	0	Drs. Mackenzie, Whitwell	3
7·1	?	?	6·7	?	?	5·5	?	?	5·9	?	?	5·0	?	?	5·8	?	?	Dr. J. G. French ...	4
?	8·8	4	?	10·1	39	?	12·6	24	8·6	4·5	29	10·0	0·1	67	12·2	0	131	Dr. S. Lynch ...	5
40·4	6·7	0	41·3	4·7	0	42·5	4·5	0	42·6	0	0	41·9	0	0	41·9	0	0	Dr. J. H. Condon ...	6
27·9	17·2	0	12·9	5·4	0	5·0	7·4	0	6·3	0·1	0	10·0	0	0	12·7	·1	0	Dr. A. G. Price ...	7
20·9	17·9	0	20·2	7·7	0	19·2	8·6	0	18·8	0	2	18·1	0	1	18·1	0	0	Civil Surgeon ...	8
16·4	23·2	0	13·6	11·8	4	8·0	8·9	68	7·9	3·3	72	9·0	0	34	10·3	0	0	Dr. Prentis ...	9
24·9	4·3	0	24·9	4·3	0	24·9	3·5	0	25·0	0	0	25·0	0	0	25·0	0	0	Dr. R. C. Bose ...	10
22·8	3·3	0	22·6	2·1	0	22·0	4·1	0	21·7	0	0	22·2	0	0	22·8	0	0	Drs. Quinnell, Fergusson	11
91·8	4·1	0	91·9	1·4	0	91·9	·5	0	91·8	0	0	91·9	0	0	91·9	0	0	Dr. J. W. Cooper ...	12
2·6	25·3	0	2·0	36·9	0	3·0	4·3	0	5·5	·2	0	7·0	0	0	7·9	·1	0	Dr. W. R. Rice ...	13
22·8	12·7	0	22·9	1·9	0	23·9	2·8	0	22·8	0	0	22·9	0	0	23·9	0	0	Dr. H. Cookson ...	14
15·3	12·8	0	11·8	17·6	1	9·0	7·4	0	10·2	0·3	1	11·6	0	1	12·4	0	1	Dr. E. Bonavia ...	15
23·3	...	...	22·0	...	...	18·4	...	0	16·0	...	1	16·2	...	...	0·9	0	...	Dr. Cameron ...	16
12·2	19·2	0	9·4	16·6	0	8·8	1·4	0	2·7	0	1	4·6	0	0	6·0	0	0	Dr. F. M. Saunders ...	17
31·0	13·8	0	26·0	18·3	0	23·2	7·1	0	24·9	1	0	27·7	0	0	30·1	0	0	Dr. H. A. Kidd ...	18
12·4	12	0	10·9	7	0	9·2	4	0	9·5	0	0	9·7	0	0	10·0	0	0	Dr. W. Moir ...	19
27·0	11·0	0	23·9	6·6	0	23·7	9·5	0	23·9	·7	0	24·1	0	0	24·7	·1	0	Dr. J. S. Howard ...	20
14·0	8·2	0	13·8	7·8	0	12·7	4·7	0	12·9	0	0	...	...	0	13·2	0	0	? ...	21
9·2	24·1	0	3·6	20·1	0	5·9	8·9	0	8·6	0·9	0	10·0	0	0	15·6	0	0	Dr. T. W. Trimnell ...	22
1·9	23·7	0	1·9	21·4	0	2·2	5·6	0	3·6	0	0	4·6	0	0	5·8	0	0	Dr. R. A. F. Renton ...	23
4·0	18·6	0	2·0	16·2	0	2·0	13·3	0	4·0	0	0	6·6	0	0	9·10	·1	0	Dr. J. Barter ...	24
23·0	...	...	13·0	...	...	5·9	...	...	10·0	...	...	15·8	...	...	19·8	...	...	Ditto ...	25
101·7	2·9	0	101·5	3·5	0	101·3	1·3		101·0	0	0	100·7	0	0	100·4	0	0	Dr. Rehill ...	26

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE VI. **1875.**

NUMBER.	STATION.	Elevation above sea-level (in feet).	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.
1	Akola ...	923	35·0	0	0	34·9	0	0	33·9	0	0	34·1	0	0	34·9	·3	0	34·9	7·6	0
2	Allahabad ...	306	54·3	0	0	55·0	0	0	55·6	0	5	56·3	0	13	57·1	0	11	57·9	?	?
3	Amritsar ...	756	12·9	0	0	12·9	1·0	0	12·9	·1	0	12·9	·1	0	12·8	1·1	0	12·8	·9	0
4	Arrah ...	191	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
5	Bhandara ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...		...	...	...
6	Burdwan ...	102	0·8	?	?	7·3	?	?	8·3	?	?	8·9	?	?	8·2	?	?	7·9	?	?
7	Calcutta (Alipore)	16	13·3	1·2	130	14·0	0	73	14·4	0	268	14·6	4·1	268	14·6	5·2	113	14·5	11·8	66
8	Cawnpore ...	...	42·0	0	0	42·0	1·0	0	41·7	0	1	40·3	0	41	38·9	0	25	37·7	·5	12
9	Chanda ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
10	Chindwara ...	...	18·2	·1	0	21·8	·7	0	24·2	0	0	26·6	·3	0	...	...	...	...	...	...
11	Commillah ...	...	1·5	4·4	0	1·9	0	0	2·3	5	0	1·8	1·9	0	2·3	5·9	0	...	25·3	0
12	Fyzabad ...	...	18·5	0	0	18·9	·4	0	19·2	0	14	19·9	0	108	20·4	0	8	...	15·4	3
13	Goruckpore ...	255	10·9	0	0	11·6	·2	0	12·2	0	0	13·0	0	11	13·9	1·7	2	14·8	5·9	0
14	Gujranwalla ...	...	25·0	0	0	25·0	0	0	25·0	0	0	25·0	0	0	25·0	0	0	25·0	1·2	0
15	Gujrat ...	...	23·0	·2	0	23·3	1·4	0	23·2	·2	0	24·0	0	0	24·3	·8	0	24·7	·9	0
16	Hissar ...	...	91·9	·1	0	91·9	1·9	0	...	...	...	...	...	...	...	...	...	...	...	...
17	Jubbulpore ...	1,351	8·9	·2	0	9·9	0	0	10·8	0	0	12·5	·1	0	13·9	0	2	15·9	·4	0
18	Kurnal ...	...	23·9	0	0	23·9	2·1	0	23·1	0	0	...	...	0	...	...	...	...	0	0
19	Lucknow (observatory).	369	12·9	·1	0	13·1	·4	2	13·5	0	1	13·9	0	345	14·8	0	74	15·7	·5	1
20	Lucknow (prison)	...	18·4	·1	0	19·1	·4	2	19·9	0	1	20·8	0	345	21·8	0	74	22·0	·5	1
21	Lullutpore ...	...	6·1	0	0	6·5	·6	0	6·9	0	0	7·7	1	0	...	...	...	...	...	...
21	Maldah ...	160	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
22	Mandla ...	...	30·6	·9	0	30·9	·1	0	31·3	0	0	31·9	0	0	...	...	...	...	...	...
23	Meerut ...	739	10·4	0	0	10·6	·7	0	10·6	0	0	11·2	0	0	12·0	1·5	0	11·0	·2	0
24	Oomraotee ...	1,206	25·3	0	0	26·5	·8	0	27·6	0	0	29·2	0	0	31·0	0	0	32·1	6·5	0
25	Pertabgurh ...	...	13·7	0	0	13·9	1·1	0	14·2	0	0	14·5	0	0	14·8	0	0	15·0	5·7	0
26	Purneah ...	125	...	...	...	14·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...
27	Raipur ...	900	17·1	1·2	0	18·0	0	0	19·9	0	0	22·2	·1	...	...	...	...	...	...	...
28	Ranchi ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
29	Saugor ...	...	6·5	0	0	8·0	0	0	10·6	0	0	12·9	0	0	...	...	...	...	...	...
30	Seonee (No. 2 well)	2,030	22·5	·7	0	25·1	·3	0	16·3	0	0	19·7	·1	0	...	...	...	...	...	...
31	Ditto („ 1 do.)	...	12·7	·7	0	14·4	·3	0	27·1	0	0	...	...	...	...	...	...	...	...	...
32	Sirsa ...	...	100·1	0	0	99·9	·9	0	100·0	0	0	104·0	0	0	100·6	0	0	100·8	·5	0

PREVALENCE *in various Stations in Bengal for the year 1875.*

1875. **TABLE VI.**

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.		
...	...	...	...	...	...	...	...	...	22·9	1·3	0	25·5	0	0	28·9	0·1	0	Dr. J. A. Laing ...	1
55·6	26·3	0	60·0	12·6	0	52·1	7·7	0	51·4	?	?	51·0	0	0	52·4	0	0	Dr. H. S. Smith ...	2
12·8	10·4	97	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. H. Whitwell ...	3
...	...	...	12·3	12·1	61	11·5	3·8	11	11·1	0	0	12·8	0	0	...	0	0	? ...	4
...	...	..	...	...	...	3·6	9·4	0	5·9	1·8	1	8·0	0	0	9·5	0	1	Dr. W. Aylen ...	5
6·9	?	?	5·9	?	?	4·2	?	?	4·9	?	?	6·0	?	?	7·1	?	?	Dr. C. H. Soubert ...	6
12·3	13·9	32	10·0	12·6	35	8·7	7·4	55	10·3	3·4	150	13·0	0	358	13·3	0	72	Dr. S. Lynch ...	7
37·9	5·7	14	...	9·1	6	39·8	7·6	3	40·9	0	0	...	0	0	...	0	0	Drs. Condon, Saunders...	8
...	...	...	...	...	...	7·0	7·9	0	9·4	4·2	0	9·9	0	0	10·9	0	0	Dr. M. Craggs ...	9
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. A. G. Price ...	10
0·6	21·6	0	0	21·1	0	·4	5·6	0	1·8	0·4	0	2·8	0	6	3·6	0	21	.....	11
21·3	9·7	46	20·1	21·7	43	20·6	·4	6	...	...	...	20·0	0	48	20·6	0	21	.....	12
14·6	8·2	0	13·8	15·9	0	11·9	3·3	0	12·4	0	0	12·5	0	0	12·5	0	0	Dr. P. Prentis ...	13
25·0	21·2	0	23·2	15·2	0	23·9	3·1	0	23·9	1·9	0	24·1	5	0	24·2	·6	0	Dr. R. C. Bose ...	14
24·9	7·4	0	23·4	12·0	0	20·2	7·0	0	18·0	0	0	17·9	0	0	17·9	1·2	0	Dr. J. Fergusson ...	15
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1·2	...	Dr. J. W. Cooper ...	16
14·9	25·1	0	2·5	8·3	0	1·7	11·5	0	4·3	·8	2	6·9	0	0	8·3	0	0	Dr. W. R. Rice ...	17
23·6	2·9	0	23·8	7·7	0	23·9	9·3	0	23·8	0	0	23·8	0	0	23·9	0	0	Dr. Cookson ...	18
16·1	7·5	6	14·3	19·4	78	11·6	13·9	401	10·8	0	40	...	0	7	...	...	...	Dr. Bonavia ...	19
22·6	7·5	6	22·2	19·4	78	20·9	13·9	401	18·0	0	40	17·7	?	7	18·0	0	...	? ...	20
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	..	...	Dr. F. M. Saunders ...	21
...	...	...	10·6	16·1	52	4·6	8·2	15	6·3	0	7	11·0	0	133	14·8	0	21	.....	21
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. H. A. Kidd ...	22
11·5	5·8	0	9·9	9·1	6	8·4	15 9	108	5·9	·1	8	7·0	0	2	7·7	0	0	Dr. W. Moir ...	23
27·3	10·6	40	22·8	8·1	12	19·2	5·4	5	18·5	3·1	0	21·5	0	0	23·9	0	0	Dr. J. S. Howard ...	24
15·0	5·4	0	14·6	17·1	0	13·4	10·4	40	13·3	0	2	13·9	0	0	14·1	0	0	? ...	25
...	...	...	4·8	14·9	0	3·7	5·0	0	3·8	0	0	4·6	0	0	5·0	0	0	Dr. Picachy ...	26
1·5	17·9	8	1·6	10·6	41	4·0	8·4	0	7·0	2·7	0	11·3	0	0	14·7	0	0	Dr. T. W. Trimnell ...	27
...	...	...	...	...	...	...	8·7	2	1	1·0	1	...	0	0	...	0	0	.....	28
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. E. Fawcett ...	29
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Dr. B. Evers ...	30
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	Ditto ...	31
100·6	5·7	0	100·6	2·5	0	101·1	9·5	0	101·1	·7	0	101·0	0	0	100·9	0	0	Dr. J. Rehill ...	32

A Monthly Statement of the WATER-LEVEL, RAINFALL, *and* CHOLERA-

TABLE VII. **1876.**

NUMBER.	STATION.	Elevation above sea-level (in feet).	JANUARY.			FEBRUARY.			MARCH.			APRIL.			MAY.			JUNE.		
			Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches)	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.
1	Akola ...	923	30·5	0	0	32·1	0	0	33·1	0	0	34·5	0	0	33·5	0	0	34·0	2·2	0
2	Allahabad ...	306	53·4	0	0	54·3	0	0	55·0	0	3	56·2	0	10	56·5	0	18	58·3	3·0	8
3	Arrah ...	191	13·9	·2	0	14·5	0	0	15·1	·7	0	15·9	0	68	16·7	1·5	827	17·0	8·2	358
4	Bhandara ...	...	10·9	0	0	12·1	0	0	13·2	·4	0	14·9	0	0	18·0	·4	0	19·3	6·2	0
5	Calcutta (Alipore)	16	14·0	0	19	14·6	2·9	226	14·8	4·3	343	15·2	·2	268	15·1	2·9	168	15·9	9·3	126
6	Chanda ...	...	11·8	0	0	12·9	0	0	13·9	·3	0	15·1	0	0	16·6	·6	0	17·2	1·2	5
7	Commillah ...	...	5·0	0	10	5·5	·7	17	5·0	2·1	74	4·3	4·9	53	4·9	10·7	0	2·9	16·8	1
8	Fyzabad ...	...	20·9	0	0	21·0	0	3	21·2	0	3	21·6	0	42	22·1	0	90	22·7	0	38
9	Goruckpore ...	255	12·7	·7	0	13·0	0	0	15·4	·2	0	14·1	1·3	0	14·7	·8	0	15·1	0·4	1
10	Gujrat ..	...	17·9	·6	0	17·9	1·4	0	17·9	3·3	0	19·3	2·8	0	20·0	2·0	0	20·2	·7	0
11	Gujranwalla ...	...	24·3	·2	0	...	...	...	24·4	2·2	0	24·5	1·5	0	24·7	1·3	0	24·9	0·4	0
12	Jubbulpore ...	1,351	9·1	0	0	10·0	0	0	10·9	0	0	12·7	0	0	14·1	1·0	0	16·7	3·2	0
13	Kurnal ...	...	23·6	0	0	23·7	0	0	23·7	1·7	0	23·5	·7	0	23·6	1·3	0	23·6	5·5	0
14	Lucknow (observatory).	369	12·9	·1	0	13·2	0	0	13·9	·7	0	14·4	0	6	14·9	0	6	15·4	3·6	137
15	Lucknow (prison)	...	18·5	0	0	18·8	0	0	19·5	0	0	20·5	0	0	21·3	0	2	22·5	0	5
16	Maldah ...	160	17·0	0	10	19·5	0	3	21·8	0	20	23·8	2·6	53	24·0	3·0	40	...	11·6	5
17	Meerut ...	739	8·9	0	0	8·6	0	0	8·9	1·5	0	9·7	1·8	0	10·2	·1	0	10·9	·1	0
18	Oomraotee ...	1,206	25·0	0	0	26·0	0	0	26·8	0	0	28·0	0	0	29·8	0·4	0	30·9	4·2	0
19	Pertabgurh ...	...	14·5	0	0	14·9	0	0	15·1	0	0	15·5	0	0	15·7	0	0	16·0	1·2	0
20	Purneah ...	125	5·6	·1	0	6·0	0	0	6·7	0	0	6·9	·7	0	7·2	4·4	2	7·4	16·5	0
21	Raipur ...	900	16·9	0	0	16·8	0	0	19·0	1·0	0	27·5	0	0	35·7	·5	0	36·2	6·1	0
22	Ranchee ...	...	...	0	0	15·2	0	0	16·8	·2	5	17·5	0	2	18·4	·9	29	17·4	8·5	19
23	Sirsa ...	...	100·9	0	0	101·2	0	0	101·3	0·6	0	101·3	0·2	0	101·6	0·9	0	101·5	1·1	0

PREVALENCE *in various Stations in Bengal for the year 1876.*

1876. TABLE VII.

JULY.			AUGUST.			SEPTEMBER.			OCTOBER.			NOVEMBER.			DECEMBER.			WATER-LEVEL OBSERVATIONS RECORDED BY	NUMBER.
Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.	Distance of Water-level (in feet).	Rainfall (in inches).	Cholera cases.		
34·2	6·2	0	33·5	6·9	0	28·6	3·2	0	29·7	0	29	32·2	0	57	33·7	0	0	Dr. C. Little ...	1
59·0	10·0	2	52·7	10·7	9	54·0	0	7	52·8	0	4	52·7	0	3	...	...	...	Dr. H. S. Smith ...	2
15·4	3·2	176	13·8	10·5	380	12·7	5·3	64	12·0	5·3	...	11·5	0	0	...	0	0	.....	3
18·9	10·5	3	14·5	13·4	50	7·5	7·7	5	8·9	·2	0	11·3	0	1	12·5	0	0	Drs. Aylen, Leckler ...	4
12·9	19·3	42	8·3	24·8	32	7·5	10·2	31	8·9	5·8	41	11·3	·1	259	12·9	0	24	Dr. Lynch ...	5
17·5	10·4	1·7	16·5	11·7	241	13·9	6·2	25	13·0	·1	0	14·3	0	0	15·1	0	0	Dr. M. Craggs ...	6
0	23·2	0	·1	20·7	0	·7	11·5	0	1·4	2·5	0	1·4	6·4	8	1·7	0	3	.....	7
23·0	4·6	13	22·4	3·3	4	22·7	9·7	13	22·5	0	14	22·5	0	4	22·9	0	0	.....	8
15·3	5·0	0	15·0	10·7	0	14·6	15·3	0	12·5	3·5	0	12·3	0	0	...	...	...	Civil Surgeon ...	9
18·8	22·3	0	16·3	0	84	16·2	0	76	16·1	2·6	0	16·3	·3	0	16·7	0	0	Dr. J. Fergusson ...	10
...	...	...	...	...	...	...	...	...	...	...	...	...	0	...	...	...	...	.....	11
13·9	27·2	198	2·0	12·7	151	1·9	12·3	1	4·9	0	0	6·7	0	0	7·9	0	0	Dr. W. R. Rice ...	12
23·7	16·2	0	23·7	10·0	0	23·7	14·0	0	23·7	1·3	0	23·6	0	0	23·6	0	0	Dr. G. Ross ...	13
16·2	7·0	109	14·7	7·5	379	14·6	3·2	181	14·7	1·0	20	15·4	0	10	16·0	0	1	Dr. Bonavia ...	14
23·3	0	13	23·0	0	13	23·0	0	8	23·9	0	0	22·1	0	1	21·5	0	4	? ...	15
16·9	11·6	0	7·6	0	0	6·8	10·0	0	5·7	3·6	0	9·5	0	2	13·9	0	71	? ...	16
11·5	7·7	0	10·4	10·5	0	10·8	2·7	0	11·1	·6	0	11·5	0	0	11·9	0	0	Drs. Moir, Harris ...	17
28·1	9·1	0	25·5	7·2	6	16·9	8·6	67	20·3	0	17	21·9	0	5	23·0	0	0	Dr. J. S. Howard ...	18
16·2	10·0	0	15·4	10·0	0	15·6	9·0	0	14·7	4·0	0	14·9	0	0	15·3	0	0	? ...	19
4·3	16·5	0	1·9	13·3	1	2·0	10·7	0	1·2	4·1	0	2·8	0	0	3·8	0	0	Dr. Picachy ...	20
20·5	13·1	0	3·2	9·8	0	1·2	13·6	0	8·1	0	0	14·7	0	0	17·6	0	0	Dr. T. W. Trimnell ...	21
7·6	14·7	74	4·1	13·1	48	6·6	6·6	3	5·9	7·0	0	8·9	0	0	11·4	0	0	.....	22
101·2	2·6	0	100·9	0	0	100·9	3·2	0	100·9	3·2		100·7	0	0	100·7	0	0	Dr. J. Rehill ...	23

A MEMORANDUM

ON

THE CHOLERA OUTBREAK OF 1881 AT ADEN.

BY

SURGEON-MAJOR T. R. LEWIS, M.B.,

SPECIAL ASSISTANT TO THE SANITARY COMMISSIONER WITH THE GOVERNMENT OF INDIA.

1882.

IN order to understand the circumstances under which cholera occurred at Aden during the months of August and September 1881, it is necessary, in the first place, to consider the immediately preceding history of the people amongst whom the disease broke out, and the sanitary condition of the localities to which it was confined.

2. The committee (composed of three Medical Officers) which was appointed to investigate the outbreak observe that, previous to the 1st of August, the only noticeable fact as regards the state of the settlement was the number of deaths amongst the starving Somalis who had come from the African coasts. In June, 161 deaths had been registered at Aden, as compared with 89 deaths in 1880, and 54 in 1879; and in July the number of deaths rose to 209, as compared with 75 during the same month of 1880 and 64 in 1879. It is manifest, therefore, that during these two months of 1881 there was some grave cause of mortality at work in the settlement. Indeed, the numerous deaths had attracted the notice of the local authorities, and a special inquiry had been instituted before any case of cholera had been recognised; the mortality having been, for the most part, attributed to dysentery and diarrhœa.

3. As to the condition of the persons and the localities affected, famine had existed in the Somali country for some time, and in consequence numbers of the inhabitants came to Aden during June and July. These wretched people had come in order to get employment as cargo-coolies, and had settled down amongst their own kinsmen in two already densely crowded localities,—Tawahi (or Steamer Point) and Maala villages. These two localities appear to be about three miles apart. The latter village is described as consisting of densely crowded huts, with a population computed to be 3,650, besides "about 780 houseless persons, who find shelter

somehow in the village." There is a large graveyard in the immediate vicinity, where, during the last three years, some 3,000 interments have taken place. The sanitary condition of Tawahi is said to be not quite so bad as this, but it is nevertheless described as most unsatisfactory: "The courtyard of almost every house contains one or more cesspools, which are dug and filled up according to the requirements of the residents." Deputy Surgeon-General Moore, in a memorandum attached to the Committee's report, describes the condition of these two native quarters as follows: "The villages lie low, the people are poorly fed, without any good water, badly housed, with the midden system in operation, and the soil impregnated with fæcal matter."

4. On the 28th July the Muhammadan month Ramazan commenced, and to the irregularities in matters of diet, etc., which are associated with the observance of this month of fasting the first indications of the manifestation of the cholera outbreak were attributed. "Bowel complaints," the Committee remark, "are not uncommon during Ramazan, owing to the gorging at night after a long fast during the day."

5. Four days after this (on the 1st August), some 60 coolies, partly from the village of Maala and partly from Tawahi (the proportion from each locality is not known), were engaged in discharging cargo from the S.S. *Columbian*, which had come into Aden the day before from Bombay. On the evening of the 2nd,* 68 coolies were again similarly employed. On the 3rd August the Port Surgeon reported to the Political Resident that "seven cases of cholera, or of a disease closely resembling it, had occurred amongst the coolies who had been unloading the cargo" of this vessel. On this date also two other cases of this disease amongst the coolies occurred, making 9 in all, the disease being strictly limited to the coolies of the Tawahi village. All of the affected coolies are said to have been working on this steamer on the 1st August, but not all of those attacked on the 2nd; and at least two of these men are said not to have been down into the hold at all.

6. On the 4th, another case of the disease was reported at Tawahi, but this time it was in the person of a Somali female resident in the locality, the wife of the French Consul's butler, who had not been on board the *Columbian;* and all endeavours which had been made to trace any connection between her and the affected coolies failed.

7. There were no more cases in the Settlement for over a week, and all danger seemed to be over; but "on the evening of the 12th an old Somali woman, a wood-seller, was found at Maala suffering from vomiting and purging, etc., and died the next day." This was the first case in the village, but others soon followed; and out of a total of 151 deaths in the settlement between 1st August and 29th

* In the printed copy of the Resident's letter of the 9th August this is given as the evening of the 1*st*, but the sentence as a whole seems to indicate that the 2*nd* is meant.

September,* 89 occurred amongst dwellers in this village alone. So far as can be gathered, none of the coolies from Maala who had worked on the *Columbian* had been attacked. Certainly none of them had been attacked for three weeks afterwards, as the first adult male (occupation not given) of this village was not attacked till the 22nd August, and the next, a *coolie*, not till the 2nd September.

8. The proportion of women and children attacked much greater at Maala than at Tawahi. Of the 109 cases which occurred at Maala, only 5 are stated to have been coolies. For the most part, the cases in this village were amongst women and children. Indeed, there were only 35 males altogether attacked here, who were over 15 years of age. At Tawahi (Steamer Point, end of the harbour) and Hedjuff, on the contrary, out of a total of 48 cases, 33 were adult males, so that the circumstance that the first 9 attacked were coolies loses much of its significance. A nearly equally large proportion of males was attacked at the very end of the outbreak, as, from the 18th to the 24th September (the date of the last case in these localities), 7 out of 9 cases were amongst adult males. Possibly, this end of the harbour is inhabited by a much larger proportion of coolies whose families are settled elsewhere.

9. The previous history of the disease amongst the coolies is not wholly inconsistent with the view that cholera may have existed even before the 1st August, though the first recognised case occurred on this date. The facts, so far as they go, show that cholera broke out amongst the coolies inhabiting the Steamer Point end of the harbour on the 1st August, though it is by no means certain that some of the very many fatal cases of bowel complaints registered before that date as dysentery and diarrhœa may not have been of a choleraic character. This much, however, is clear, that, coincidently with the circumstance that a certain number of coolies, whilst engaged in their ordinary occupation of discharging a cargo, were attacked with a disease which was recognised as cholera, it so happened that this ship was a steamer, laden with pilgrims and merchandise, from a port where cholera is but rarely absent, *viz.*, Bombay; but, as will be seen below, it has yet to be shown that the first person who was reported to have died of the disease had, as a matter of fact, ever been on board the vessel.

10. With regard to the cause of the outbreak, the Committee remark that they are "generally of opinion that the disease was imported into Aden by the S.S. *Columbian*. The theory of the Port Surgeon is that it was introduced by the cargo, which he thinks could have been contaminated by cholera discharges while being shipped in Bombay;" and Dr. Moore in the Memorandum above referred to, writing of this part of the subject, adds—"It is more likely that the germs of the disease were secreted among the rice-bags in the hold, and liberated when the bags were moved by the coolies."

11. But the theory is not borne out by the facts. Two cases of the disease were

* No European or Native soldiers suffered from the disease. The Committee mention that the only European attacked was "a woman in the military hospital at Steamer Point, who had been suffering for some time from dysentery and fever. She died."

reported to have occurred amongst the coolies on the very first day on which they were engaged in unloading the cargo of the vessel,* one of which appears to have proved fatal during the night and the other on the day following. It is, however, not satisfactorily shown that the first fatal case had any connection with the *Columbian:* the man's name does not appear to have been ascertained, and he is not included in the tabular statement appended to the Committee's Report. All that is said concerning him is contained in the following sentence in paragraph 9 of the Report:—"As it was reported that another coolie who had been employed on board the S.S. *Columbian* had died during the night, inquiries were at once instituted;" but, so far as can be gathered, no precise information concerning this fatal case was obtained, and the only noteworthy result of the inquiry appears to have been the discovery of two other cholera-affected coolies in the bazaar.

That germinating organisms should be capable of producing such alarming symptoms, and even death, within so few hours after their assumed introduction into the system, has not, so far as I am aware, ever been seriously suggested before, and certainly all my own experiments with such organisms are wholly opposed to any such assumption. Nor would the view, that the disease may have been caused by some other kind of virus or poison acquired by handling the rice bags on board the *Columbian* be much more tenable than the germ hypothesis, for it would appear that the rice, subsequent to leaving the ship, was handled and eaten in the settlement with complete impunity. Nor, further, can it well be assumed that the poison was of a gaseous character, generated in the hold of the ship, for at least two of the coolies attacked were known not to have been down in the hold at all, and none of the pilgrims or crew were in the slightest degree affected.

12. Moreover, the previous and subsequent history of the vessel is strongly opposed to the idea that she was tainted. The Port Surgeon had visited the vessel on her arrival after a 13 days' voyage direct from Bombay,† and reported that "the cargo was inspected by him and he found it sweet and clean; the hold of the ship was also dry and clean;" and further, "the ship was free from disease." The mortality on board pilgrim ships is usually exceedingly high, owing to the aged, sickly, and not unfrequently moribund condition of a large proportion of the pilgrims who start for Mecca. On this particular voyage five died out of a total of 650 pilgrims, the deaths in all these cases being ascribed to old age and general debility.

13. Two of the crew also died, one being a stoker, who died on the 29th July, 11 days after leaving Bombay and three days before reaching Aden. Of this latter casualty, the Committee report—"The stoker was entered in the return by the Native Doctor in medical charge as 'colic.' The circumstances were inquired into at the time, and were considered so free from suspicion that when cholera appeared in Aden among

* There are some discrepancies between the account given of the earlier cases in paragraph 9 of the Committee's Report and the tabular statement appended to it. The data as given in the text are adopted here.

† The date of departure from Bombay is given as the 17th in one of the papers and as the 18th in others.

the coolies, further inquiries were not made. Notes were not made at the time, and the special facts regarding the deaths cannot now be recollected. On the return of the vessel, inquiries were made, but the Native Doctor had left her, and the Captain recollected little about the case except that he was ill for two or three days. The case was associated, to the best of the recollection of the Port Surgeon, with fever." The Committee are, however, of opinion that a "certain amount of suspicion must be attached" to this case. Why, it is rather difficult to understand, seeing that, if there be one disease which a Native Doctor, or indeed any other native of India, can readily distinguish, it is cholera. Not the faintest suspicion of anything of the kind had been entertained until so long after the event that minute details of the illness had escaped the recollection of everybody who could be questioned as to them.

14. The subsequent history of the vessel in the voyage to Jeddah and the return voyage to Bombay also goes to show that this case had nothing to do with the cases of cholera which afterwards happened at Aden, and, in fact, to exonerate her entirely from all connection with the cholera outbreak at this settlement; for not only during her stay of a whole week in port was there "no sickness amongst the crew, nor amongst the pilgrims on board either before or after the lower hatches had been taken up for the purpose of discharging cargo," but she disembarked the pilgrims at Jeddah without having had any cholera, and called again at Aden on her return journey to Bombay equally free from suspicion. As the Aden Committee remark: "during her voyage to Jeddah and during her return voyage to Bombay there was no sickness on board."

15. The probability is that the disease had been acquired on shore, rather than on board ship. It is true that the earlier cases of the disease which were reported were almost entirely restricted to coolies who had been working on board the steamer; and it is not impossible that the hard labour involved in discharging cargo, especially in the case of fasting coolies, may have expedited the manifestation of the already latent disease amongst them; but further than this nothing can be said. Any other hard labour at this particular time would probably have acted in the same way. The fact that, of the 50 or 60 coolies collected from various parts of the harbour, the first cases of the disease were strictly confined to men residing in one particular locality, points most assuredly to the conclusion that the disease itself was acquired in the locality where these particular persons dwelt rather than on a ship in which coolies from various parts of the Settlement had chanced to spend a few hours together. It is mentioned in the Committee's report that the men, "after finishing their work, went to their houses at Tawahi or Maala;" but none of the coolies from Maala or other parts of the Settlement were attacked for some weeks subsequently, and of those who were attacked, it is not known that any one of them had been on board the *Columbian*. Moreover, as has already been mentioned, one of the earlier cases of the disease occurred in a woman who resided in the same locality as the persons first affected, but who had neither been on board the ship, nor had she associated with those coolies.

16. As to the question of the vitality and transportability of the supposed cholera

germs, Deputy Surgeon-General Moore, in his Memorandum above referred to, writes: "If there be any truth in the generally accepted views that the poison of cholera is contained in the evacuations of the cholera-stricken, the conveyance of the germs of the disease to Aden may be accounted for as plausibly and as probably as anything which cannot be positively demonstrated."

The analysis which has been made of the facts of this outbreak in the foregoing paragraphs shows on what exceedingly slender grounds such a conclusion is based, even assuming that what are referred to as "the generally accepted views" are correct. But when there are grounds, based on the results of very many carefully conducted observations, for questioning the correctness of such "generally accepted views," the position taken by the Committee and by Dr. Moore is still more untenable. Dr. Moore writes further: "The vitality of the germ would be preserved by the absence of the great purifier—oxygen of the atmosphere—amongst the densely-packed rice-bags in the hold." The discovery of a cholera germ has frequently been "authoritatively" announced, and organisms of the most varied character have been described as being the essential cause of the disease, but none of the announcements have stood the test of inquiry; moreover, even if it had actually been demonstrated that a characteristic germ had been detected in cholera, it could hardly be assumed that its power of maintaining its vitality was lower than that of other germs. The opinion which at present is predominant as to the vitality of most of the organisms associated with diseased conditions is that they are, practically, indestructible—that, according to some, they can survive even the heat of boiling water. If cholera be due to germs of this kind, the wonder is that not only Aden but also more distant ports, such as Brindisi, Marseilles and Southampton, have not, during recent years especially, been the scenes of frequent outbursts of the disease. But what are the facts as regards even Aden, which is the nearest of these ports to India?

17. Previous to 1881, cholera had not appeared at Aden for fourteen years, and the circumstances under which it appeared then present many points in common with those observed during the recent outbreak; but the explanation which was suggested as to its origin was totally different. The question of the disease having been brought by a ship does not appear to have been thought of on that occasion.

18. On the 17th June 1867 two cases of the disease were observed in the persons of Arabs at the Settlement, one labouring inside and the other outside the fortifications. On the following day, 13 other cases occurred amongst a completely isolated population of some 200 liberated slaves who were located on the Twin Rocks in the harbour, about $1\frac{1}{4}$ miles from the shore. That same evening the disease broke out in the Maala village and other localities along the shore. In 1867, as in 1881, the disease did not break out amongst the European troops, two cases only having been reported, of which one was fatal.* The epidemic appears to have been of short duration,

* Proceedings of Sanitary Commissioner for Bengal, October 1867, page 430.

and the total number of deaths in the Settlement is stated by the Assistant Political Resident to have been 57.*

19. It would seem that, previous to the appearance of the disease at Aden in 1867, it was known to have been prevalent "in the little District of Aleecan in the Foodthlee country," about 40 miles distant from the Settlement, and the sudden outbreak of the disease at Aden was attributed to "choleraic blasts" from that direction. In 1881, however, cholera does not appear to have been observed in any of the outlying districts previous to its sudden manifestation in the Settlement, so that the possibility of accounting for it on the supposition of a "choleraic blast" could not well be entertained. It does not appear to have occurred to the observers of either epidemic that the disease could have originated at or near the locality in which the sufferers dwelt.†

20. The possibility of the disease being of local origin has been very generally ignored. The idea that cholera originates *de novo* in India, and in India only, and is thence disseminated by means of human intercourse, and still further diffused by rivers or by the wind, has taken so firm a hold on the minds of the medical profession and the public at large, that any other conceivable method of the origination of the disease is almost completely ignored, notwithstanding that a long array of facts has been recorded, which prove that epidemic outbursts of the disease occur under conditions when none of these factors can be shown to exist.

21. The influence of the promulgation of current theoretical views has many disadvantages. What the essential cause may be is wholly unknown, but surely it is wiser frankly to avow our ignorance than to promulgate purely theoretical doctrines which tend to divert the attention of Governments and individuals from the necessity of getting rid of known local causes of ill-health, and which, if carried to their logical conclusion, would seriously interfere with personal liberty, and prove very embarrassing to the commercial intercourse of nations.

22. The past history of Aden furnishes strong evidence as to the non-transportability of cholera by ships. So does that of the Andamans. For, since the occupation of Aden in 1839, we have accounts of five epidemics of cholera as having occurred there—in 1846, 1858, 1865, 1867, and lastly, in 1881. The Suez Canal was opened in 1869, and yet, notwithstanding the enormously increased communication between India and

* *A Statistical Account of the British Settlement of Aden* by Captain F. M. Hunter, Assistant Political Resident, 1877, page 177. In this work, Captain (now Major) Hunter refers, under the heading "Natural Calamities," to three other cholera epidemics at Aden previous to that of 1867. The first, in 1846, after a heavy fall of rain—the disease breaking out at Mokha, under similar circumstances, on the very same day. The attack lasted 33 days at Aden, and "about 386 persons were carried off, of whom 20 were Europeans." The second epidemic was in 1858, on which occasion 15 Europeans and 560 Natives died from the disease; and the third was in 1865—May to August—when 1 European and 53 Natives died.

† Evidence illustrative of this aspect of the general question will be found in a report submitted a few years ago by Dr. Douglas Cunningham and myself: "*Cholera in relation to certain Physical Phenomena:* Being a contribution to the Special Cholera Inquiry sanctioned by the Right Honourable the Secretaries of State for War and for India," and which was published in the *Thirteenth Annual Report of the Sanitary Commissioner with the Government of India;* and also (in part) in the *Practitioner* for April and May 1878.

Aden since that period, the interval between the last epidemic and that of 1867 is considerably greater than the intervals between the two preceding epidemics. A practical experiment of this kind, and one on so large a scale, cannot be lightly set aside in favour of purely theoretical views, however ingeniously and earnestly those views may be advanced, and however eminent those who promulgate them may be.*

23. In conclusion, it has been considered desirable to enter thus fully into the details of the recent cholera outbreak at Aden, and especially as regards its supposed direct importation from Bombay by means of the S. S. *Columbian*. The view that the disease was so introduced has already been unhesitatingly adopted by some sanitary authorities in Europe; and, possibly, in the course of a few years, unless meanwhile the opportunity be taken of placing the facts on record, the mere "opinion" of the present time may come to be referred to as a well-authenticated incident, and the history of the S. S. *Columbian* be cited as an instance of the transportability of cholera by means of ships, regarding which there can be no question.

SIMLA,
20*th June*, 1882.

* The convict settlement in the Andaman Islands likewise furnishes a striking illustration of the non-transportability of cholera by means of ships. Notwithstanding that it is within three days of India and two of Burma, and that constant communication has been kept up between it and the two countries during the last five-and-twenty years, not a single epidemic of cholera has occurred amongst a population of (at present) over 10,000 convicts, although cases have on some occasions been imported there, and have died from the disease after landing. Nearly all the food for the convicts is imported from Calcutta—a place from which cholera is never wholly absent.

A MEMORANDUM

ON

THE "COMMA-SHAPED BACILLUS" ALLEGED TO BE

THE

CAUSE OF CHOLERA.

BY

SURGEON-MAJOR T. R. LEWIS, M.B.,

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SEPTEMBER 1st, 1884.

WITH a view of studying the phase which the cholera question has now entered upon, in consequence of the publication of the results of the investigations of the German Cholera Commission in Egypt and India, I availed myself of the opportunity which the present vacation at the Army Medical School afforded of proceeding to Marseilles, where the disease has been prevalent since the end of June. Sir Joseph Fayrer was so kind as to enlist for me the valuable assistance of Dr. Le Roy de Méricourt, Médecin en Chef of the French Navy, who, in various ways, did his utmost to further my wishes. Dr. Marroin, the Chief of the Sanitary Department in Marseilles, was so good as to introduce me to the authorities of the Pharo Hospital, where the cholera cases are treated, and where, with the permission of the principal medical officer, Dr. Trastour, I was able to renew my acquaintance with the disease, and to collect material for studying afresh the microscopy of the intestinal discharges.

Before, however, referring to the results of my own observations, it will be convenient to epitomise the published history of the German Commission; to point out the salient features of the results of their investigations in Egypt and in India; and to make a few brief comments on such of the circumstances and conclusions as appear to call for notice. Shortly after the arrival of the Commission in Egypt, Dr. Robert Koch reported, on behalf of himself and his colleagues, that no special micro-parasites had been discovered in the blood, the lungs, the spleen, the kidneys, in the liver in cholera, but that the intestinal mucous membrane was permeated

by certain bacilli which nearly resembled in size and form the bacilli found in glanders. As is well known these bacilli are straight, and are, in fact, uncommonly like the ordinary microphytes associated with decay. Dr. Koch also states in connection with this subject that he had, previous to proceeding to Egypt, found similar bacilli in the intestinal mucous membrane of four natives of India, but that he had then looked upon them as due to merely post-mortem changes. When he came to Egypt, however, and found these same bacilli in the intestines of perfectly fresh cases, he felt that an important link was furnished towards establishing the identity of the disease in Egypt with Indian cholera.

It is highly probable that the specimens from India which Dr. Koch had examined were those which were sent, at the request of the Imperial Health Department in Berlin, by the Sanitary Commissioner with the Government of India. These consisted of numerous dry-cover glass specimens of blood which I had collected from several cholera patients, and of portions of the viscera of four natives who had died of the disease. All these were examined by me before they were despatched, and portions of each were reserved for further study. I had heard nothing further of them, but the publication of the remarks above referred to in Dr. Koch's Report of September 17th, 1883, from Alexandria, recalled them to my mind, and I was glad to infer that my own negative results had been confirmed in Berlin. As already observed, no importance had been originally attached to the organisms which were present in the intestinal mucosa. During the last six months I have examined hundreds of stained microtome-sections of these four, and of other specimens of cholera intestines in my possession, and have found that when the mucosa is infiltrated with microphytes at all they are either micrococci, bacteria, or long-oval, and straight bacilli.

In the report of the Commission, dated Calcutta, February 2nd, 1884, Dr. Koch, however, announces for the first time that the specific bacillus of cholera is curved or comma-shaped, and not straight, so that apparently it had become necessary to abandon the microbe first fixed upon. Assuming that the four specimens from natives of India which had been examined by Dr. Koch were those which passed through my hands, the evidence they furnish seems to be in accordance with this view, as in not one of them have I been able to detect any invasion by unmistakable "commas," though at least one of the specimens may fairly be characterised as abundantly infiltrated (in the manner described by Dr. Koch) by straight (and as I prefer to call them) putrefactive bacilli. Judging from my own experience, therefore, any extensive infiltration of the intestinal mucous membrane in cholera by comma-shaped bacilli must be exceedingly rare ; and this, I believe, is likewise the experience of the members of the late French Cholera Commission, MM. Straus, Roux, and Nocard, whose acquaintance I had the pleasure of making at M. Pasteur's laboratory on my return through Paris.

Whilst at Marseilles I had, as already stated, opportunities of observing

numerous specimens of choleraic excreta, and found that comma-shaped bacilli were, more or less conspicuously, present in all of them, though in some instances more than one slide had to be examined before any could be satisfactorily detected. It may also be mentioned that some of the discharges in which these organisms were present manifested an acid reaction when tested with litmus paper. As Dr. Koch himself remarks, the proportion which the comma-shaped bacilli bear to other organisms in the dejecta varies greatly. In some instances only one or two specimens are to be found in the field of the microscope, while in others they are very numerous, and Drs. Nicati and Rietsch (who are at present engaged in the study of the disease at Marseilles) were so kind as to show me a specimen of choleraic material they had obtained from the small intestine, in which the "commas" existed almost to the exclusion of all other organisms. This is a condition, however, which, I understand, is exceedingly rare. On the other hand, I have seen samples of choleraic dejecta in which totally different organisms prevailed to a like exclusion of others; and in one instance at Marseilles spirilla of various sizes and forms were the most conspicuous of the micro-organisms present. So far, therefore, the selection of the comma-shaped bacilli as the *materies morbi* of cholera appears to be entirely arbitrary.

Dr. Koch and his colleagues have adduced no evidence to show that they are more pernicious than any other microbe; indeed, as a matter of fact, the sole argument of any weight which has been brought forward in favour of the comma-shaped bacillus being the cause of cholera is the circumstance that it is more or less prevalent in every case of the disease, and that the German Commission had not succeeded in finding it in any other. With regard to the suggestion that the cholera process may in some way favour the growth of these bacilli, and that these are not necessarily the cause of the disease, Dr. Koch remarks in the report from Calcutta above cited, that such a view is untenable, inasmuch as it would have to be assumed "that the alimentary canal of a person stricken with cholera must have already contained these particular bacteria; and, seeing that they have invariably been found in the comparatively large number of cases of the disease both in Egypt and India—two wholly separate countries,—it would be necessary to assume, further, that every individual must harbour them in his system. This, however, cannot be the case, because, as already stated, the comma-like bacilli are never found except in cases of cholera."

Had Dr. Koch and his colleagues submitted the secretions of the mouth and fauces—the very commencement of the alimentary canal—to a careful microscopic examination of the same kind as that to which they have submitted the alvine discharges, I feel persuaded that such a sentence as the foregoing would not have been written, seeing that comma-like bacilli identical in size, form, and in their reaction with aniline dyes, with those found in choleraic dejecta, are ordinarily present in the mouth of perfectly healthy persons.

[Since this memorandum was submitted I have observed that Dr. Koch states, in his recent address on the subject, that after his return to Berlin he had examined, amongst other things, the secretions of the mouth for comma-shaped bacilli, but had found none; and, further, that he had consulted persons of much experience in bacterial researches as to whether they had ever seen such organisms, and was told that they had not. It may be of assistance to future observers if I give the dimensions of half-a-dozen comma-shaped bacilli, as found in each of the following situations: (*a*) In the alvine discharges of three cholera-affected persons; (*b*) in the small intestine of a person who had died of the disease, and in whom they existed almost to the exclusion of other organisms; (*c*) in a cultivation of them in agar-agar jelly; and (*d*) in the secretions of the mouth of three healthy persons, ranging from four to fifty years of age. The measurements were made (with the valuable assistance of Mr. Arthur E. Brown, B.Sc. Lond.) under a magnifying power of 1,000 diameters, a Powell and Lealand's $\frac{1}{16}$th of an inch oil-immersion lens, with a wide angle condenser, being used.] The results appear in the following table :—

Length and Width (in Micro-millimetres) of Comma-shaped Bacilli in Choleraic Material and Secretions of the Mouth in health.*

Numbers.	Choleraic Material.					Secretions of the Mouth in Health.		
	Alvine discharges.			Intestinal contents. [autopsy.]	Cultivation in agar-agar jelly.			
	I.	II.	III.			I.	II.	III.
	μ	μ	μ	μ	μ	μ	μ	μ
1	2·4 × 0·40	2·0 × 0·60	1·1 × 0·25	2·0 × 0·40	1·6 × 0·40	2·0 × 0·50	1·4 × 0·35	1·5 × 0·50
2	2·6 × 0·40	2·5 × 0·65	1·8 × 0·35	1·2 × 0·40	1·4 × 0·60	1·3 × 0·35	2·0 × 0·40	1·3 × 0·50
3	2·0 × 0·50	3·2 × 0·70	2·0 × 0·60	1·5 × 0·45	1·8 × 0·50	1·6 × 0·40	1·7 × 0·40	1·0 × 0·30
4	2·2 × 0·45	3·0 × 0·70	3·0 × 0·70	1·3 × 0·60	2·0 × 0·50	1·2 × 0·35†	1·3 × 0·45	1·2 × 0·40
5	2·8 × 0·35†	2·5 × 0·60	2·2 × 0·50	2·1 × 0·50†	2·6 × 0·45†	2·2 × 0·65	2·1 × 0·50	2·7 × 0·50
6	1·5 × 0·35	2·0 × 0·50	1·6 × 0·40	1·2 × 0·50	1·1 × 0·35	2·0 × 0·40	2·8 × 0·40†	1·4 × 0·55

There is no difficulty in putting this statement to the test; and to any one acquainted with the methods ordinarily adopted for staining and mounting fungal organisms of this character, no special directions need be given. The procedure followed by me to demonstrate these "commas" in the saliva is precisely that adopted for finding them in the dejections. A little saliva should be placed on a cover-glass (preferably in the morning before the teeth are brushed), and allowed to dry thoroughly, either spontaneously or aided by a gentle heat. The dry film thus obtained should be floated for a minute or two with one or other of the ordinary solutions of aniline dyes adopted for such purposes, such, for example, as fuchsine, gentian-violet, or methylene blue. The cover should then be gently rinsed with distilled water, and the film re-dried thoroughly. The preparation may now be

* One Micro-millimetre (μ) = ·001 millimetre [= $\frac{1}{25000}$"].

† S-shaped comma bacilli.

mounted in dammar varnish or Canada balsam dissolved in benzol, and should be examined under a $\frac{1}{12}$th or $\frac{1}{16}$th of an inch oil-immersion lens.

As in choleraic discharges so in the saliva, the number of the comma-shaped bacilli will be found to vary greatly in different persons, and at different times in the same person. Sometimes only one or two "commas" will be seen in the field, at others a dozen may be counted, and, occasionally, little colony-groups of them may be found scattered here and there throughout the slide.

It may be remarked in passing, and as bearing upon what has been already said regarding the general absence of comma-shaped bacteria from the intestinal mucosa itself, that they do not appear to manifest any special tendency for attacking the decaying epithelial scales of the mouth, but that, on the contrary, they are for the most part found free in the fluid, the epithelium being studded with other bacterial forms.

Persons who have not been in the habit of examining dried saliva-films will probably be surprised at the number and variety of the organisms which are, more or less, constantly to be found in the mouth, and especially at the number of spirilla with which the fluid is generally crowded.

The alvine discharges in cholera sometimes swarm with precisely similar spiral organisms, and indeed, as has long been known, the fluid exuded into the intestines in this disease is peculiarly suitable for the growth of these and allied microbes. But, so far as my own experience—dating from 1869—of the microscopic examination of such a fluid goes, all the microphytes ordinarily found in it are likewise to be found, to a greater or less extent, in the secretions of the mouth and fauces of unaffected persons. And with reference to the comma-like bacilli found in cholera, to which such virulent properties have been ascribed, I shall continue to regard them as identical in their nature with those ordinarily present in the saliva until it has been clearly demonstrated that they are physiologically different.

[This memorandum was originally published in the *Lancet* of Sept. 20th, 1884, through the courtesy of the Director-General of the Army Medical Department, Sir Thomas Crawford. "The culminating point of importance in the memorandum is the announcement that curved or comma-shaped bacilli, identical in size, form, and in their reaction to aniline dyes with those found in cholera, are ordinarily present to a greater or less extent in the secretions of the mouths of perfectly healthy persons" (*l. c.* p. 497).]

PART II.

OTHER DISEASES.

THE FUNGUS DISEASE OF INDIA:*

A REPORT OF OBSERVATIONS

BY

T. R. LEWIS, M.B., AND D. D. CUNNINGHAM, M.B.

CHAPTER I.

THE NATURAL HISTORY OF PARASITIC FUNGI GENERALLY.

THE importance of undertaking a series of systematic observations with a view to elucidate the nature of the connection between certain disease-processes and growths of a vegetable character has for a long time been impressed upon us, and we have for several years past kept records of investigations bearing more or less directly on this subject. Hitherto, however, our reports on fungi and allied organisms have referred to the question of the actual presence of any such vegetations, not palpably adventitious, in connection with certain special diseases and particularly with cholera. Having failed to satisfy ourselves of the existence of sufficient evidence to support the doctrine that any such growths are necessarily associated with these particular classes of disease, we decided on ascertaining, if possible, whether in the diseased conditions in which characteristic fungoid growths are known to exist beyond dispute, the latter must necessarily be regarded as the actual cause of the particular malady. In undertaking this work we were aware that it was taking a step backward—treading the ladder a step lower down than that on which we commenced our work. We saw no alternative, however, but to do this, as personal observation had taught us that certain fundamental data, which we had originally taken for granted as established, were not entitled to such unreserved reliance. Some of these observations we have now proposed to detail.

We are desirous that it should be understood that it is not our intention to discuss the purely botanical questions, which, though so intimately associated with phyto-pathological studies, belong, nevertheless, more to the province of the professional botanist than to that of the pathologist: such questions, for example, as the relation existing between fungi and algæ. The true character of the vegetations which occupy

* From the Eleventh Annual Report of the Sanitary Commissioner with the Government of India.

debateable land between fungi and algæ—aquatic fungi, *Achlya*, *Saprolegnia*, and the like—is of itself a question sufficiently difficult to occupy the undivided attention of botanical experts for years to come, so that we do not consider it necessary to offer any excuse for leaving such questions to those in whose province they lie and restricting ourselves to their pathological bearing. We are the more inclined to this course, as there are, unfortunately, only too many examples on record of the great hindrance to the advancement of our knowledge of the causation of diseases which has been occasioned by pathologists and botanists having trespassed on each other's domains. This is an evil which it shall be our endeavour to avoid.

It will be convenient for many reasons to restrict ourselves to the employment of one term whilst describing the particular vegetations under discussion; and as it is only very rarely that what, in the present state of our knowledge, are regarded as "algæ" manifest truly parasitic proclivities, we shall refer to them as "fungi" simply.

The opinion that fungi are endowed with the power of inducing disease is not an unnatural one, seeing that they are the most constant of all the attendants on disease and decay. Their germs are known to be universally distributed, and were it not for the peculiar conditions required for their development, their depredations would be past conception. Fortunately nature has fixed a very potent barrier between a sporule and the organized material upon which it may chance to settle, and which, were it not for this barrier, it would speedily appropriate to its own use. This barrier is healthy life. It has yet to be shown that the living matter of the tissues of any animal, so long as it retains its vitality undiminished, is liable to succumb to the attacks of a fungus. Should a spore be brought into contact with bioplasm whose vitality is impaired, however, the changes in the latter which such impairment implies may be of such a kind as to transform it into most suitable pabulum for the nourishment of the former. The impairment of vitality may be due either to disease or be a normal process, the result of age: whether the change be normal or abnormal matters little to the fungus—it grows and multiplies wherever it finds material exactly suited to it.

It is the less vitalized portions of animals that are prone to epiphytic attacks—portions which have little or no power of repair. Hence the epidermic tissues, the wing covers and articular plates of flies and insects, branchial plates of fishes, and the like, are the parts on which fungi are most commonly found. In such cases the vegetable organisms do not attack the living material, but what has ceased to undergo any active nutritive changes and is virtually dead, excreted material. With regard to those instances in which it is known that fungi are associated with the existence of disease during life, it is far from proven in any single case that the disease was not present prior to the fungus. For example, it is most strongly maintained by many observers that it is only the sickly silkworm that is ever attacked by fungi, and that inoculation can only be effected after the worm has sickened.

There is another barrier to the unlimited development of fungi, although of less import so far as the growth of the mere vegetative portion of the fungus is concerned, and that is the adaptability of the soil for its nourishment. Even with regard to animal parasites this feature is particularly evident not only with respect to the entozoa, but epizoa also are limited to certain animals and even to certain defined areas of the body. This law applies as strictly with regard to fungi as to the higher plants; one spore will sprout and rapidly cover a surface with mould where another will not manifest the slightest indication of growth.

Some leaves become the hosts of certain fungi only—their entire surface being equally liable to attack; whereas it is only on a very limited area of other leaves that another species will develop at all. In Calcutta, for instance, the leaves of *Hibiscus rosæ sinensis*, at particular times of the year, almost invariably present a fungus on their surface, whose growth is strictly limited to the point on the under-surface, where the petiole enters the lamina of the leaf, and which does not spread beyond this spot notwithstanding the production of an abundant development of mycelium and sporular elements. It is evident that at this spot a peculiar secretion is present which furnishes suitable pabulum for the nourishment of the particular fungus.

As already mentioned, even some animals, just as in the case of the leaf, while in perfect health, appear to furnish a secretion which throughout life and without detriment to their health, supports the growth of some particular fungus at a particular spot; and it is not improbable that the morbid secretions resulting from disease in others furnish the special pabulum necessary for the development of the particular kinds of fungi constantly forming so prominent a feature in the appearance of such animals both before and after death.

Of animal tissues none are more frequently affected by fungi during life than the bodies of insects of various kinds; but whether the tissues are ever attacked during perfect health is, as already mentioned, a question still warmly disputed. This point, although it may appear, at first sight, to be of very trifling moment, is nevertheless of the utmost importance in estimating the nature and the extent of the influence which fungi exert on the production and maintenance of disease. The fact that the entire bodies of flies, beetles, bees and such-like, when affected with fungi, are found, when examined after death, to have been permeated through and through by mycelial threads, would be most significant were it known beyond doubt that the tissues in question were not diseased before the advent of the fungus —that the fungus did not follow the disease as the roots of a plant creep towards a stream.

Should it, however, be demonstrated that in any disease the growth of a fungus in a living subject can be limited not only to certain tissues, but to certain completely isolated portions of such tissues, the question would be very much simplified; such evidence would point to the dependence of the fungoid growths on some peculiar

condition in those localised spots. It would, further, be evident that however extensive, in some cases, the modification in the aspect and effects of the disease by the development of a fungus might be, the interpretation to be put upon the *rôle* of the latter in the malady must be in accordance with the fact that its development depended upon some previous change in the normal tissues.

What our own conclusions are with regard to this matter in connection with the disease in which we have specially studied it, will be gathered from the following account of a series of observations extending over a period of several years. We have endeavoured to curtail the narrative as much as appears to be consonant with the desire that readers may be able to infer the extent and to know exactly the character of these observations, and thus be able to judge whether or not we have worked at the subject in such a way as to entitle us to form an independent opinion.

CHAPTER II.

THE EVIDENCE RECORDED IN FAVOUR OF THE FUNGAL ORIGIN OF THE MADURA-FOOT AND HAND-DISEASE, OR FUNGUS-DISEASE OF INDIA.

THE disease which we have selected as being the most suitable for the purpose we had in view—the "Fungus-disease of India"—has been investigated with the greatest diligence and care by Dr. H. Vandyke Carter of Bombay, to whom the profession is indebted for by far the fullest information it possesses with regard to the affection, and who certainly was the first to describe accurately the minute characters of the black particles frequently found in connection with it. His published observations date as far back as March 1860, since which period several communications have appeared from his pen.* These he has summarised and supplemented in a very able monograph on the subject published during the past year.†

Dr. E. W. Eyre also has written a concise description of the disease, as witnessed by himself (*Indian Annals of Medical Science*, No. XII, pp. 513 and 813, 1860). He mentions that Garrison-Surgeon Godfrey of Madras was the first to call attention to the affection, under the designation of "Tubercular disease of the foot," and that he published an account of some cases observed by him since 1844, in the *Lancet*, 10th June, 1846. The malady has, therefore, been known to the profession for more than thirty years.

No special interest was, however, taken in the matter until Dr. Vandyke Carter,

* Transactions of the Medical and Physical Society of Bombay, Vol. VI, 1860.
Ditto ditto, Vol. VII, 1860.
Ditto ditto, Vol. VIII, 1862.
Transactions of the Pathological Society of London: Vol. XXIV, 1873.

† "Mycetoma, or the Fungus-disease of India"—London: J. and A. Churchill, 1874.

as already mentioned, the Reverend M. J. Berkeley,* and Mr. H. J. Carter, F.R.S., † published the result of their personal observations. The papers of these distinguished observers were followed by those of many others, so that the bibliography of the disease at present occupies no inconsiderable space in our medical literature. Those of our readers who may desire further details on this point will find a careful *resumé* of the greater part of what has been written concerning the disease in Dr. Carter's valuable monograph. It will be sufficient for our purpose merely to refer, generally, to what the three writers above mentioned have written, more especially to the writings of Dr. Vandyke Carter and Mr. Berkeley, with whom chiefly rest alike the credit and the responsibility which is attached to the observations and the deductions which have been promulgated with regard to the disease.

According to Dr. Carter the affection manifests itself under two forms, each presenting a different state of the same disease: (1) the *black* or *melanoid*, and (2) the *pale* or *ochroid*, varieties. There is, further, a phase of the disease characterised by the presence in the tissues of pink granules, so that, practically, the malady has been described as presenting three varieties. Although the phase of the disease last-mentioned is of rare occurrence, it is, nevertheless, of great significance in connection with the theory of the origin of the disease now commonly accepted—a view typified in the name "Mycetoma" given to it by Dr. Carter and adopted by the London Royal College of Physicians in its "Nomenclature of Diseases."

As far as external appearances go, the two leading forms have much in common. There is considerable distortion of the foot or hand affected, an increase of size, more or less marked, in all directions; there are numerous, somewhat mammillated, apertures, communicating with cavities of various sizes and channels of various lengths in the subjacent tissues. The materials which escape through these apertures differ in the two forms: in the dark variety the fluid which oozes from the foot frequently contains brownish-black granules, in appearance not unlike the rougher description of gunpowder; whereas in the pale variety little particles, bearing a considerable resemblance to fish-roe, are very commonly seen.

On section also the state of the hard and soft tissues presents much in common: (*a*) numerous lined cavities generally communicating with each other by means of sinuous channels; (*b*) softening and excavations, more especially of the tarsal and carpal bones, but frequently also involving the long bones; and (*c*) the packing of these cavities with a hard, dark substance in the black variety, and with a more or less soft, yellowish, fatty or gelatinous substance mixed with globular roe-like particles in the other.

It is with reference to the nature of these two substances, so different in appearance to the naked eye, that Dr. Vandyke Carter's observations and deductions are of such

* Intellectual Observer, No. X, November 1862. Journal of Linnean Society, Vol. VIII, p. 135, 1865.

† Annals and Mag. Nat. Hist., Vol. IX, 1862. Journal of the Linnean Society, Vol. VIII, 1865.

importance; not only of importance in relation to the particular malady in which these peculiar substances are found, but to that class of diseases—a class at present very large and still on the increase—whose *existence* and *extension* is attributed solely to the pernicious influence of vegetable parasites.

Briefly stated, Dr. Carter describes the dark material in the first variety of the affection as consisting almost entirely of a fungus in its sclerotial form, *i.e.*, one of the "resting" states common to fungi and somewhat analogous to the "resting" states of perennial plants—examples of which are furnished by bulbs and tubers of various kinds. The substance found filling the cavities in the pale variety is considered to be indicative of an advanced stage of the disease due to "a change—seemingly a degeneration"— of the darkened masses.

The fact that a pink mould has been developed in connection with specimens of both varieties has served as a link between the dark and the pale material; and this link has, so to speak, been completed by the circumstance that Dr. Carter has observed a case of the disease—practically forming, as before mentioned, a third variety, in which a pink coloration of the tissues, associated with innumerable pink particles—"fungus-bodies," were its characteristic features. Here, therefore, we seem to have the key to the arch which sustains the hypothesis that the Madura-foot and hand-disease is originated and propagated by means of a peculiar fungus.

It is consequently of importance that all who desire to form a correct estimate of the value of so important and popular a doctrine—of importance were it only because of its popularity—and absolutely incumbent on such as by their writings promulgate views based, as far as the human subject is concerned, almost entirely on this peculiar malady, to examine this particular point closely. To the best of our knowledge, the following particulars comprise all that has been published with regard to the pink mould and the pink particles. With regard to these two sets of observations, it may be noted that, in the first instance, attention was arrested by the occurrence of pink particles comparable to "red-pepper grains" in the diseased tissue, accompanied by some pink staining.

Some time subsequently it was observed that a pink or crimson-coloured mould had developed on separate specimens of the ochroid variety on two different occasions, and on particles of it placed in boiled rice-paste:—(1) on the exposed portion of a foot which had been macerating in water for eighteen months—the growth extending "even to the sides of the bottle;" (2) on a preparation which "had been put into a bottle with some fresh spirit" for preservation about two months previously; the part of the specimen which was above the surface of the fluid, owing to the evaporation of the spirit, acquired "a red tinge, and soon after there appeared a thick layer of crimson mould;" and (3) in connection with some soft particles from a foot which had been placed in some boiled rice-paste a day after amputation: ten days afterwards buff and green moulds were observed, and a few days later a red tint was distinguishable, and stained filaments were traced to the particles.

A similar mould was obtained on four occasions in connection with fragments of black particles obtained from specimens of the dark or melanoid variety:—

(1) Some of these particles from a newly amputated foot were mixed with a little *cotton soil* "moistened with animal juices" and kept for two years and nine months unopened. It was then observed that a thin reddish film had appeared on the still moist surface like that noticed on the salt pans in the marshes near Bombay.

(2) During the same period similar fresh particles, obtained from the same source as in the foregoing experiment, were placed on rice-paste and set aside in a corked bottle. This also remained unchanged for nearly three years, "when on opening the bottle and removing its contents into an open glass-cell, a *red mould* speedily made its appearance and spread luxuriantly: it had not, however, a clear connection with the fungus particles, but seemed to spring up independently of them upon the rice wherever this was exposed to the air."

(3) Black particles were taken directly from another foot and placed in some moist ground rice. About six months afterwards a reddish tinge, passing on to crimson, was observed on the rice starch. "*The black particles have remained unchanged* to all appearance, and the red stains do not surround them, but may spring up unconnectedly." (The italics are ours.)

(4) A set of three experiments was undertaken:—(*a*) black particles and rice-paste, (*b*) rice-paste only, and (*c*) black particles which had been kept dry in a box for two or three years (mixed with rice-paste?).

When examined within a month the first was unchanged; the second, *i.e.*, the rice-paste alone, presented a suspicious reddish tinge in one part; and the third was covered with a pink growth which grew "equally and spread everywhere, but its commencement had no more apparent connection with the unaltered black masses than in the other cases."

A fifth series was undertaken, but as the specimens were lost, details have not been given.

With regard to these observations, Dr. Carter writes that at first he did not appreciate the significance of this pink-tinted growth until he had learnt Mr. Berkeley's opinion that the peculiar mould was "the perfect condition of the species."

Mr. H. J. Carter made somewhat similar observations, and both observers communicated their results to the Rev. Mr. Berkeley, who, as being the most experienced and distinguished mycologist in England, was of all persons the most likely to be able to throw light on the nature of the growth.

Mr. Berkeley also undertook some cultivation-experiments with material obtained from Bombay—Dr. Vandyke Carter supplied some alcohol-preserved specimens, and Mr. H. J. Carter some fragments of the material preserved in dried rice-paste. No peculiar growth was developed in connection with the former, but a pink mould appeared on some rice-paste to which some of the dried fragments had been added. Although the growth of this mould did not proceed sufficiently far to bring all its fruit to

perfection, still, taking into consideration the experience gained by the observers in Bombay as well as his own, Mr. Berkeley felt himself justified in pronouncing the mould to be new to science. Though having many points in common with *Mucor*, it, nevertheless, did not accurately coincide with all the characters of that genus, but approached more nearly to the genus *Chionyphe*—every hitherto known species of which had only been observed to grow on melting snow. This pink mould was consequently added to the list of species of this genus and named *Chionyphe Carteri*.

As already intimated, it is not our intention to discuss the purely botanical phase—the phase which Mr. Berkeley naturally restricts himself to—but with regard to the assumed relation of this pink mould with the disease under consideration, the opportunity may be taken of pointing out here (1) that it was observed to grow without any appreciable connection with the black particles—the only substance associated with the malady in which the existence of fungoid elements has been definitely established; (2) that these particles themselves were, on every occasion, found to be wholly unchanged; and (3) that the pink mould grew as luxuriantly in connection with preparations which had been preserved in spirit as in connection with specimens of the morbid tissues which had not been subject to the influence of any preservative fluid.

CHAPTER III.

A DESCRIPTION OF SPECIMENS ILLUSTRATIVE OF THE PALE VARIETY OF THE FUNGUS-DISEASE OF INDIA.

THE materials forming the subject of examination were derived from entire preparations of both upper and lower extremities affected by the disease, and from numerous smaller specimens of the morbid tissues from other cases. Considering the rarity with which the disease attacks the upper extremity, we were fortunate in obtaining two excellent specimens in which it was so localised. Taken together, the specimens presented a series of typical examples of various degrees of both the so-called pale and dark varieties of the disease, while one of them afforded an abundant supply of the peculiar red particles which are only very rarely found in association with it—in fact, there appears to be only one well-authenticated case hitherto recorded—so that we believe that we have had what may be regarded as very fair opportunities for the study of the morbid appearances present, and of the lesions and pathological changes affecting the tissues.

It is a matter of regret to us that we have had no opportunity of studying the disease during life owing to its extreme rarity in Calcutta—the disease, apparently, not being endemic in this part of India, and consequently only presenting itself in the form of isolated, imported cases. We hope, however, that we may yet be able to complete our observations in this respect at some future period in one or other of the

endemic areas of the disease, and feel that the careful study of the specimens which have been at our disposal has rendered us much better prepared for the clinical study of the disease and the investigation of the conditions under which it is developed than we could otherwise have been.

We owe the materials which we have examined to the kindness of Dr. Cornish, the Sanitary Commissioner for Madras; Dr. Gamack, Civil Surgeon of Madura; Dr. Mark Robinson, at present acting for Dr. Gamack; Dr. Kenneth McLeod; Dr. Downie, Ulwar; and to the Civil Surgeon of Cuddapah; all of whom have, from time to time, either themselves supplied us with valuable specimens or have induced others to do so. We wish also specially to acknowledge the obligation which we are under to Dr. McConnell, the Professor of Pathology in the Calcutta Medical College. He has not only aided us by supplying us with numerous specimens of the disease, but has placed the valuable collections in the Pathological Museum under his care at our disposal for purposes of examination and comparison.

The amount and variety of the work involved in working out the subject has been considerable. Not only has it been necessary carefully to study the condition of the tissues and the nature of the morbid materials present in the various forms under which the disease presents itself, but a close examination of other morbid tissues and products in other diseases affecting similar anatomical regions has had to be undertaken, together with a study of the nature and properties of various natural and artificial oleaginous compounds and concretions; and numerous and varied attempts at cultivation of the morbid materials, with study of the resultant organisms; and of the effects of reagents on them and other vegetable growths.

We take up the consideration of the Pale or Ochroid variety of the disease first as, in many ways, less obscure and complicated in character than that in which the black colouring of the morbid material forms such a striking and characteristic feature. It will perhaps be best in the first place to give a brief description of the appearances presented by some of the specimens which we have examined, and subsequently proceed to consider the common features occurring in them all and, apparently, essentially connected with the disease. We shall then be in a position to state our views in regard to the pathology of the affection together with the grounds on which these are based.

SPECIMEN I.—This consisted of a foot and ankle. The foot was much thickened, especially towards the ankle, and was straightened on the latter so as to point in a manner resembling that in cases of *Talipes equinus*. The toes presented much less distortion and tendency to be turned upwards on the foot than is, in our experience, usually the case in specimens of the disease. The general appearance of the specimen is shown in the woodcut on the following page (Fig. 5).

Numerous openings surrounded by raised margins, or opening on the summits of elevated tuberculations, were present on both upper and under-surfaces of the foot. They communicated with channels lined with smooth membranous tissue and leading into the substance of the foot. On making a section, the knife passed readily through the

tarsal and metatarsal bones and through the lower extremity of the tibia. All these bones were extremely soft and opened-out in texture. The degree of softening varied in different places; in many it had proceeded so far as to render the bones quite spongy and so friable as to be easily broken up under the finger-nail even on the surface, and in some places the softening had proceeded to such an extent as to replace the bone-texture entirely by a soft greasy pulp. In those cases in which the softening was only partial the outline of the bones could yet be traced, but in other places the latter were quite indistinguishable from the surrounding degenerated tissues. One or two examples of cavities in the substance of the bones were also present,—smooth and lined by a distinct membrane. Close to several of the articulations there was some slight roughness of the surfaces of the bones. The muscular and tendinous structures of the foot were well preserved and apparently unaffected by the disease; but there was a general thicken-

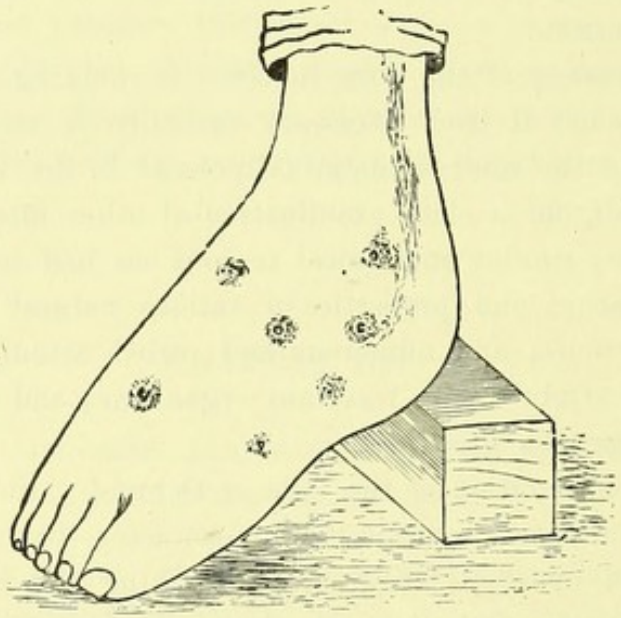

Fig. 5.—Outline sketch of a specimen of the Pale Variety of the Fungus Disease of India.

ing of the areas normally occupied by fat and connective tissue, and all the structures were much obscured by the extreme abundance of fatty matter present. There were numerous cavities in the substance of the foot, lined by smooth membrane and containing oily and fatty material. Some of them were quite isolated, but others communicated with one another, and with the exterior by means of the channels previously alluded to. One cavity of large size was situated immediately above the metatarsal bones; it was lined by a gelatinous pulp of orange-yellow colour and contained a large quantity of oily matter.

The extremely oily condition of all the tissues was most remarkable, the bones were reduced to mere masses of soft fat penetrated and supported by remains of the osseous tissue; and it was impossible to touch the preparation without smearing the fingers, knives, and other instruments with a thick coating of greasy oil, while the spirit in which it was preserved was covered with a thick layer of large yellow oil globules.

The oily matter was throughout generally more or less fluid, but in some places both in the bones and soft tissues there was an abundance of distinct small glistening particles, of a white colour and composed of dense radiating masses of acicular fat crystals. Nowhere was there the slightest indication of the presence of any brown or black matter, or of any peculiar substance save the profusion of oily matter. The amount of thickening in the masses of connective tissue rendered it probable that a certain amount of elephantoid condition had coincided with the pathological changes proper to the disease under consideration, and the distortion of the foot was in this case to be ascribed in great part to this, although, no doubt, the action of the tendons and muscles on the softened fatty bones also contributed to cause the distortion.

Careful microscopical examinations were made of all the tissues and materials present, but in no case did they afford the faintest evidence of the presence of any fungal or

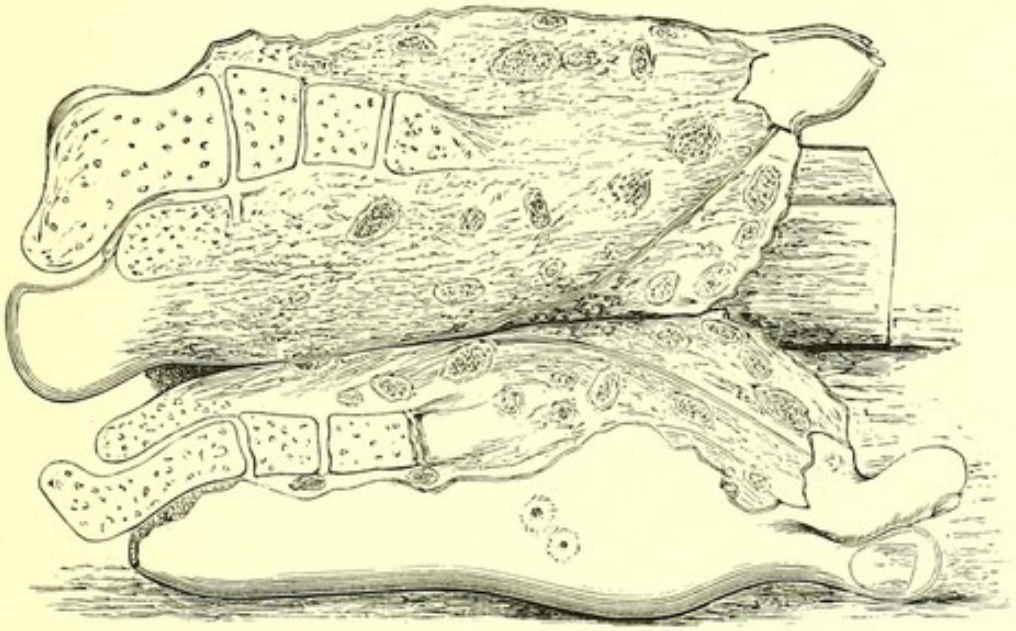

Fig. 6.—Section of a foot affected with the Pale Variety of the disease.

fungoid bodies or of anything save degenerations of the normal elements of the tissues.

SPECIMEN II.—This preparation, which has already been referred to by Dr. Fayrer in his "Clinical and Pathological Observations in India," consisted of a foot and ankle.

The foot was much distorted: there was great thickening anteriorly, and the two were elevated and curved upwards from their bases. Numerous crater-like openings on the surface communicated with channels, lined by smooth membrane and leading into the interior of the foot. It was carefully divided longitudinally, the knife passing readily through the bones of the tarsus. As may be observed in the accompanying figure of the specimen (Fig. 6), the line of section passed through the centre of the *os calcis* posteriorly, and between the second and third toes anteriorly, passing between the metatarsal bones of these toes and through the remains of the middle cuneiform and scaphoid bones. On examining the divided surfaces, the foot was seen to be greatly thickening

below the line of the bones. The thickening had occurred both below and above the plantar fascia, foci of degeneration being present in both situations, although more abundantly below than above the fascia.

These foci consisted of cavities lined by smooth membrane and containing gelatinous and caseous matter, or distinct roe-like masses of minute rounded particles. These roe-like aggregations were quite free in the cavities, and were surrounded with more or less mucoid or gelatinoid semi-fluid material. In some instances the cavities appeared to have penetrated the plantar fascia, or rather, perhaps, to have passed between the several strips of its tissue. They presented a curiously symmetrical arrangement in some places, especially immediately beneath the skin, where the normal series of fat masses was in great part replaced by a row of cavities containing roe-like masses. These cavities in many cases coincided in size and form with the loculi usually occupied by fat—their lining membrane, although somewhat thicker, being composed of the same anatomical elements as those normally separating and limiting the masses of fat, and only differing from the normal partitions in being denser and containing a somewhat larger proportion of common connective tissue in relation to the elastic fibres. In some cases the cavities were perfectly isolated, occurring among healthy fat-masses, in others they were close to one another, only separated by their limiting membranes; in others they communicated directly or indirectly with one another, and in some cases two or more appeared to have coalesced entirely, so as to form one large, frequently somewhat irregular, cavity. In almost all instances the openings on the surface of the foot were found to lead by means of channels into such cavities, whilst another series of channels connected cavities or sets of cavities with one another. Similar cavities containing degenerate material were also present in the subcutaneous fat of the dorsal aspect of the foot.

The bones, although softened and oily in texture, were in great part distinctly traceable, especially towards the inner half of the foot, but even here the base of the second metatarsal bone was disorganised and completely obscured by the degeneration. The muscular and tendinous structures were little, if at all, affected, and appeared to have contributed to the deformity of the foot by their action on the soft and weakened bones, although the greater part of the extreme flattening of foot was, no doubt, due to the extent of the disease in the fat, and connective tissue.

The membranous lining of the cavities and the various materials contained in the latter were carefully examined microscopically. The caseous matter and roe-like masses were found to consist of oily matter in various conditions. The caseous matter was formed of yellowish amorphous material mingled with oil globules; it was readily acted on by liquor potassæ, and when treated with this reagent frequently gave rise to an abundance of tubes, filaments, and globules of myeline. The particles forming the roe-like masses were composed of a large central mass or nucleus of similar caseous matter densely clothed with radiating crystals. These,

when the particles were compressed beneath a cover-glass, appeared as fringes of a feathery aspect surrounding a central mass of amorphous matter, and when a current was induced by the addition of a drop of water to the slide, the crystalline fringes were seen to become bent in the direction of the current, as may be observed in the adjoining woodcut (Fig. 7). Prolonged and careful microscopic examination failed to reveal the presence of any fungoid elements notwithstanding the use of most various reagents. Some of the particles having been first treated with chloroform were immersed in liquor potassæ and kept under observation during several weeks. They appeared at first to be partially dissolved, and were subsequently deposited in the form of a whitish gelatinous layer on the side of the test tube in which they were kept. The material of this layer was found to consist almost entirely of beautiful tubes, filaments, and cysts of myeline of every conceivable form, affording an excellent opportunity for the study of the many curious and complex forms which matter of such nature is capable of assuming (*vide* Fig. 8, page 356).

Fig. 7.—A roe-like particle under a moderate power, with feathery crystals adherent to it; the latter curved at one part owing to a current being induced on the slide. × 100.

Specimen III.—A foot and ankle-joint (Plate XXVI, Fig. 1). This foot was enormously enlarged transversely, and the toes were shortened, turned upwards, and more or less drawn backwards into the foot, so that the latter presented a peculiarly thick, "stumpy" aspect. The shortening and upturning of the toes were specially marked in the case of the second one, where the distortion had proceeded so far that the tip of the toe projected upwards on the dorsum of the foot; the nail resting on the dorsal surface of the foot and only becoming visible when the toe was forcibly bent forwards in some degree. On both dorsal and plantar aspects of the foot, there were numerous mammillated projections surrounding orifices of the diameter of crow or goose-quills, which communicated with channels penetrating the substance of the foot, and from which soft granular matter could be forced by pressure. Amputation had been performed through the lower fourth of the leg.

A section was carried completely through the foot, dividing the tissues from the space between the second and third toes, to the centre of the calcaneum and thence upwards through the astragalus and middle of the tibia. The entire section was performed with a knife from an ordinary dissecting case, which passed through the bones with the greatest ease save towards the upper portion of the tibia, where a certain amount of resistance was experienced and where the bone presented an apparently normal aspect. The disease of the tarsal bones was extremely advanced. The astragalus retained its normal outline, but was extremely open in texture internally, the spaces in the bony tissue being full of yellow oily matter, and here and there containing distinct aggregations of roe-like particles. The greater portion of the front half of the os calcis was reduced to a soft pulp containing irregular excavations bathed in

oily fluid and abounding in roe-like particles. The posterior half resembled the astragalus in condition generally, but contained several distinct cavities of considerable size containing roe-like bodies. The remainder of the tarsal bones in the line of section were almost entirely reduced to a softened, undifferentiated mass, riddled with irregular cavities, and in which mere fragments of bone remained distinguishable, the arch of the foot being entirely obliterated, and even the faintest indications of the individual bones having been destroyed. The bases of the first phalanges of the toes were the first recognisable osseous elements anteriorly, and even these were extremely softened, opened out and oily in texture. Considering the extreme degree of the degeneration, it was curious to observe how little the muscular tissue was affected, the fibres being apparently unaltered, and presenting well-marked striæ in almost all the fragments which were subjected to microscopic examination.

The fatty tissue throughout the entire foot was, however, very much altered and degenerated. The subcutaneous fat showed various stages of degeneration with great distinctness, the nests of fat-cells appearing in three distinct forms. (*a*) The normal loculi of connective tissue filled with apparently healthy fat, the capsule containing the fat being seemingly unaltered, and the cells of the latter not being readily separable from it. This condition was specially present towards the posterior portion of the sole and behind the heel. (*b*) Loculi which presented pretty much the same appearances as those in the previous form, but in which the contents were more or less gelatinous, caseous, or waxy in appearance and consistence; in many cases, in fact, approaching more or less closely in their characters to those presented by the ceruminous secretions of the ear. Two or more loculi were here and there blended to a greater or less extent, or were almost united into a common cavity of a larger size. The fatty contents were easily removed, leaving cavities closely resembling those presently to be described, and only differing from them in the less consistent nature of their lining membranes. (*c*) The cavities here were enlarged, or rather the septa between the normal loculi were more or less completely absorbed or thrust aside, in some cases having been entirely obliterated, and in others persisting in a more or less fragmentary condition as threads or pillars of connective tissue. These cavities were occupied by masses of circular, yellowish-white grains or particles, like small seeds or ova, aggregated into masses of various sizes, and evidently forming the roe-like bodies so constantly described as characteristic of the discharges and tissues in this variety of the Madura-disease.

The cavities in the deeper tissues of the foot were exactly similar in appearance to those occupying the subcutaneous fat, and, like them, contained oily and fatty matter in various forms, but principally in that of roe-like masses. Many of the cavities, both superficial and deep, were quite isolated and unconnected with any others, or with the surface, whilst others communicated freely with one another either directly or by means of channels, and some of the more superficial also communicated with the exterior in a similar fashion. In the latter case, the channels connected

with the cavities opened on the mammillations previously alluded to as occurring on the integument of the foot. The lining membrane of the channels and cavities —whether occupying the subcutaneous or interstitial adipose tissue, or the sites of disintegrated bone—was throughout the same; and on microscopic examination was found to consist of connective tissue abounding more or less in elastic fibres.

The various modifications of fatty matter above described could be seen to merge into one another by insensible degrees throughout the preparation. In some loculi individual lobules of fat had passed more or less completely into the ceruminous condition, whilst the remaining ones were to all appearance perfectly normal, and in those cavities in which all normal fat had disappeared the contents shaded off gradually from yellowish, ceruminous, amorphous masses through a series of intermediate forms into the characteristic roe-like particles. Apparently a still further stage of the degeneration was represented by specimens of the latter, which, in place of their normal yellowish colour and waxy consistence, presented a glistening white colour and friable texture, and resembled, when in mass, small lumps of chalk. It will be seen that, in so far as the unaided senses were concerned, no hard and fast line could be drawn between the normal fat of the tissues at one end of the series of modified forms and the thoroughly degenerate chalky masses at the other, for an almost infinite series of intermediate steps was present. The same held good on careful microscopic examinations also. Starting with normal masses of fat, the series could be traced through gradual stages in which the contents of the cells became more or less completely condensed into waxy amorphous mass, whilst the cell walls became more and more obscured until a uniform mass of the former, still retaining a somewhat cellular arrangement, was all that remained. From this the series proceeded through a set of forms characterised by increasing condensation of the material and the appearance of feathery crystals on the surface passing on into the characteristic fringed roe-like particles (Fig. 7, p. 349), and culminating in the chalky masses of acicular crystals.

All the varieties of morbid material present in this case were carefully ransacked with the aid of the most various reagents and appliances, with the view of ascertaining the presence of any vegetable organisms or other foreign bodies as constituents of them, but entirely in vain. It was quite clear that in this case, at all events, we had merely to deal with a degeneration of the normal constituents of the tissues, unassociated with, and uncomplicated by, the presence of any extraneous elements.

SPECIMEN IV.—This consisted of a portion of skin and subcutaneous tissue from the sole of the foot in a case where the diseased condition was limited to the textures between the plantar fascia and the integument of the sole of the foot.

There were numerous slight elevations on the surface of the skin, beneath which minute dark-coloured points could be seen. These were hard to the touch, and in some cases small openings could be detected leading inwards towards them from the surface. On dissecting down upon them these points were found to consist

of isolated dull, yellowish, more or less spherical bodies of firm waxy consistence (*vide* Plate XXVII, Fig. 5). They were easily compressible, and spread out into a greasy smear on the surface of the glass on which they were examined. Both as regards microscopical appearance and effects of reagents they coincided exactly with the ceruminous masses of the previous specimen (pages 350-1) or with the nuclei of the common roe-like particles. The subcutaneous fat was carefully examined under a low magnifying power, and a sprinkling of similar bodies was detected in and removed from it. It was quite evident that they were local degenerations of portions of the normal fatty tissue, lobules or aggregations of fat cells being discovered in various stages of modification from mere slight condensation of the contents of the cells up to the formation of firm, waxy grains or concretions, which, in the more advanced cases, had lost all organic connection with the surrounding tissues, and were manifestly only capable of acting as foreign bodies (Plate XXVII, Figs. 5-6).

Microscopic examinations here too failed to show any traces of the presence of vegetable organisms, the degenerated material consisting solely of waxy, amorphous matter. No distinct roe-like particles were to be found by the unaided senses, and the microscope showed an entire absence of fringes or other crystalline forms in connection with the concretions. In this case the degeneration was evidently merely commencing, and had not yet advanced so far as to pass on to the formation of crystals, but as the case was one of comparatively short duration—the patient had only suffered from the disease for one year—this was only what might, perhaps, have been expected, and the probability is that the absence of the characteristic roe-like particles was due to this and not to any peculiarity in the morbid process.

SPECIMEN V.—A collection of the roe-like particles discharged from the foot in a case previous to amputation.

These presented no special peculiarities, and were composed of the usual aggregations of masses of fatty matter of waxy consistence fringed with feathery crystals. No signs of fungal or other vegetable elements could be detected in them.

SPECIMEN VI.—A specimen of diseased tissues from a foot, comprising both bones and soft parts, which had been dried in the sun. This was obtained in order to provide materials for cultivation, and presented nothing in any way peculiar. It contained an abundance of the characteristic roe-like bodies, and, as usual, was devoid of all fungal elements.

SPECIMEN VII.—This consisted of transverse sections through the lower portion of the leg in a case of this form of the disease.

All the fatty and fibrous tissues were extremely gelatinous, and the preparations were characterised by an extreme profusion of minute, bright rose-coloured bodies, which were sprinkled over the surface of the tissues and formed an abundant deposit at the bottom of the fluid in which the specimen was preserved. They were so abundant as to give the sections the appearance of having been sprinkled with red pepper, and at once to attract attention to their presence even whilst still in the

bottle in which they were preserved. On careful examination they appeared to be mainly, if not wholly, confined to the surfaces of the sections, as in no instance could it be clearly ascertained that they were present in freshly exposed portions of the tissues. As a rule, they appeared to be quite loose in the softened gelatinous matter of the degenerated tissues, but here and there they seemed to be entangled amongst, or attached to filaments of, connective tissue. Their intimate nature will be described farther on, but it may in the meantime be stated that they showed no signs of containing any fungal elements, or of being in any way related to such bodies; and that we are strongly inclined to believe that the number of them present in the specimen increased whilst it remained in our hands.

CHAPTER IV.

PHYSICAL CHARACTERS AND RELATION TO SURROUNDING TISSUES OF THE MORBID PRODUCTS USUALLY ASSOCIATED WITH THE PALE VARIETY OF THE AFFECTION.

HAVING now given some examples of the materials illustrative of this form of the disease which we have examined, and which have formed the basis for our views regarding its nature and causation, we may next proceed briefly to state what these views are. We shall confine our attention at present to it, and leave the question of its relation to the other variety to be discussed at a subsequent page. We have, as the above illustrative cases may serve to show, totally and absolutely failed to identify the presence of any fungal or other parasitic elements in any of the specimens of the disease which we have examined, and we believe that we have good grounds for denying the necessary coincidence, and consequently much more the causative connection of the presence of any parasitic organisms at all with the morbid changes present.

We have studied very various stages of the disease, and in all alike has there been an absence of any demonstrable parasites, but more than this, we have been able to trace out a series of modifications of the elements of the normal tissues terminating in lesions and degenerations which are quite capable of accounting for all the appearances present in the most advanced stages, and which therefore render the assumption of the essential agency of a parasite not merely unnecessary, but even inadmissible. Why this degeneration should occur, and why it should be specially localised in the extremities, we cannot say, but we believe that we have good grounds for the assertion that this variety of the disease primarily is essentially a degeneration of the fatty tissues independent of the local presence or influence of any parasites whatever.

In a very early stage of the disease, as for instance in Specimen IV (page 349), we found mere alterations in the normal fat, and in more advanced cases we have

been able to trace such degenerative changes onwards. That the degeneration is essentially one of the fatty tissues, is not only evident from the nature of its ultimate products, but from the localisation of the primary foci of the deceased action. These foci are invariably situated in localities abounding in fat, in the subcutaneous adipose tissue, in the sub-fascial or inter-muscular connective tissue, and in the cancellated tissue of bones and specially in spongy bones abounding in fatty matter.

The degenerative process appears to consist in a gradual condensation and inspissation of the contents of the fat cells, with a coincident diminution and disappearance of the vascular supply of the lobes and lobules of the adipose tissue and an ultimate solution of the interstitial connective tissue and cell membranes. The latter process appears to occur by mucoid or gelatinoid softening, and results in the formation of the gelatinous matter in which the altered constituents of the fat are so frequently found to be embedded. Whether the affection, however, primarily originates in the fat itself, the connective tissue, or the lymph-spaces, we are not in a position to state. Once such a degenerative process has occurred, the masses of fatty concretions and gelatinous substance resulting from it are virtually portions of dead matter, really external to and unconnected with the economy, and little prone to change save in so far as the fatty constituents tend towards the assumption of crystalline forms. Such foreign, extraneous substances must naturally tend to excite a certain amount of irritation in the surrounding tissues, causing a thickening of the connective tissues around them, and the gradual formation of cyst-like cavities so characteristic of the disease. A further progress of the irritant action may ultimately lead these cysts to open into one another, thereby forming irregular cavities, and cause the formation of channels lined with a membrane of connective tissue, and in many cases opening externally and allowing of the escape of the products of the degeneration.

The degree to which the degeneration may proceed varies greatly in different instances, as also does the proportion which the fatty and gelatinous products bear to one another. In some cases we find roe-like masses and other crystalline elements in comparatively small proportion, while the tissues are bathed in an abundance of oleo-gelatinous fluid. In other instances the separation of the fatty and gelatinoid materials is found to have advanced to a high degree, and distinct cavities containing roe-like masses of fatty concretions characterise the tissues. Once, however, the gelatinoid degeneration of the connective tissues and an alteration in the fat cells with obliteration of the vascular supply has occurred, it is not necessary that distinct concretions should form in order to cause the degenerate matter to act as a foreign body and lead to the formation of cavities, with channels and openings for its discharge. Specimen I (page 345) afforded a characteristic example of this; for in it, although the degeneration was widely diffused and the characteristic openings were present on the surface, the amount of roe-like, crystalline concretions was comparatively small.

The amount and nature of deformity present in different instances, vary with the degree to which the various tissues have been involved, and to which an hypertrophy

of the fat and connective tissues has coincided with the degeneration. In almost all cases there is an apparent thickening of the affected extremities, which is sometimes real and due to thickening of the masses of connective tissue in some places, and to their being opened out into cavities in others. An apparent thickening may, however, be to a great extent independent of any hypertrophic changes, being in many cases due to a folding or crushing together of the tissues induced by the action of the muscles and tendons on the softened non-resistent bones. In the case of the lower extremity, the mere mechanical weight of the body in many cases contributes to the production of deformity, as may frequently be seen in cases where the calcaneum has been much affected by the degeneration. The precise nature of the deformity is, of course, determined by the degree in which all these factors come into play; but one of the most common results of their action on the lower extremity (in which the disease most frequently occurs) is an obliteration of the arch of the foot and a turning upwards, or even backwards, of the toes. The latter phenomenon is due to muscular action, and may cause it to appear as though a great amount of thickening of the tissues of the sole had occurred, when in fact little or nothing of the kind has taken place.

In describing the specimens, reference has been already made to the characters of the various morbid products constituting the ultimate results of the degeneration, and this may suffice in so far as the majority of them are concerned. There are, however, one or two points regarding which somewhat fuller details appear to be necessary. These refer to the ordinary fatty concretions, and specially to the character and nature of the peculiar coloured particles which occurred in such abundance in Specimen VII (page 352).

In so far as the common fatty concretions are concerned, it is rather a caution as to the interpretation of phenomena connected with them than any further description which we wish to give here. As previously mentioned, these concretions, under the influence of various reagents, very readily give origin to an abundance of that curious and ill-defined substance which Virchow has termed myeline. A development of myeline is specially prone to occur where portions of the fatty matter, roe-like masses, etc., freshly removed from an alcoholic preparation, are subjected to the action of liquor potassæ. The multifarious and highly complex forms of tubes, filaments, globules and cysts, which may frequently be observed to become developed—shooting out and, as it were, growing from the globules and aggregations of fatty matter, are wonderful, and such that it would hardly be believed to owe their origin to any such process or material were development not distinctly traceable through all its stages.

From the extremely organised nature of their appearance, they are, as Fig. 8 on the following page will show, peculiarly liable to be mistaken for fungal growths, especially by those who are unused to the practical study of such bodies and to the various appearances presented by complex oily compounds, and it is necessary that very great caution should be exercised in the interpretation of such phenomena. Bodies of this

nature are usually very transitory, but they may persist for weeks, as was exemplified in the preparation referred to in the description of Specimen II (page 347), and they may in some cases be even suffered to dry up more or less completely without losing their peculiar forms.

The physical conditions, moulding a plastic semi-fluid material into peculiar forms, probably produce much the same effects, whether the material acted upon be endowed with vitality or not, so that the close resemblance of these organic to truly organised forms need be no special cause for surprise. We have, however, in the course of investigation been more and more strongly impressed with the necessity of caution in deciding on the nature of equivocal bodies merely from their outward appearance and morphological characters, and we believe that this necessity is onew hich holds good, not only in regard to the morbid products of the disease forming the subject of

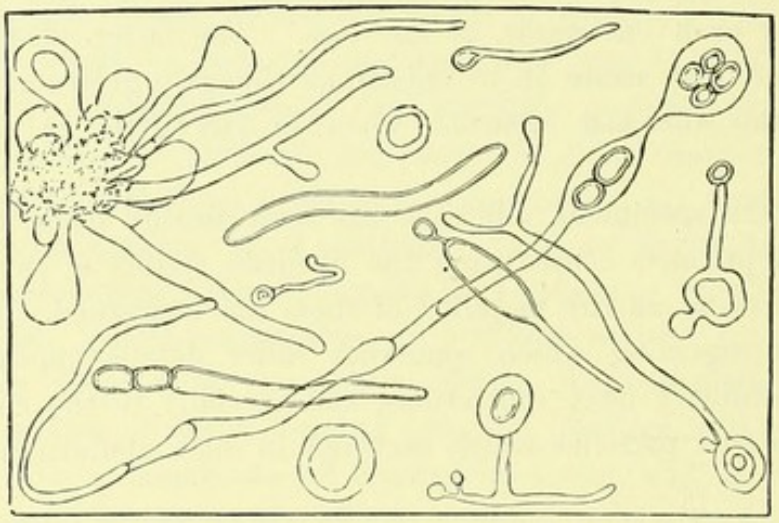

Fig. 8.—Various fungi-like forms assumed by "Myeline" × 500.

the present report, but also with equal force to the interpretation of the appearances present in many other cases, and specially in the so-called parasitic skin diseases.

CHAPTER V.

PHYSICAL CHARACTERS AND INTIMATE NATURE OF THE RED PARTICLES OCCASIONALLY ASSOCIATED WITH THE PALE VARIETY OF THE FUNGUS DISEASE OF INDIA.

THE peculiar red particles referred to as being present in Specimen VII (page 352) demand more special consideration. As previously mentioned, on consulting the literature of the subject, it will be found that they are of such rare occurrence in connection with the disease that they can hardly be regarded as characteristic of it. Considerable weight has, however, been laid on their occasional presence, in favour of the fungal or parasitic nature of the degeneration, and we therefore gladly availed ourselves of the excellent opportunities which we had of closely investigating their nature.

In the present case the red colouring was absolutely confined to the particles; there was no staining of the tissues in connection with which they occurred. The particles, as previously stated, immediately attracted attention, as an abundant sprinkling of minute, bright red points or grains scattered over the tissues and deposited on the sides and bottom of the vessel containing the preparation. Their size varied considerably in different instances, but in the greater number ranged from $\frac{1}{120}''$ × $\frac{1}{170}''$ to $\frac{1}{90}''$ × $\frac{1}{120}''$. Their outline was generally rounded or oval, but many more or less irregular forms also occurred; these might, however, be almost always ascribed to the occurrence of fracture or rupture of the commoner forms, or to the union of several particles into an aggregate (*vide* Plate XXVII, Figs. 3—4).

The figures in the plate show the principal varieties of forms present, and that they were all modifications of the round or oval primary one. Many of them, in place of having an even surface, were more or less tuberculated or knotted; others were constricted in the middle, or even actually separated into two portions with an intervening space; others were aggregated longitudinally in a moniliform fashion, or formed irregular heaps; whilst others again were ruptured and, as it were, unfolded. The colour, when fully developed, appeared bright vermilion to the naked eye, and under the microscope passed from this into a rosy carmine, according to the degree of magnifying power employed. The colour of the particles was, however, by no means uniform in intensity in all instances, a faint red or pinkish tinge being all that could be determined in many; whilst in others the red colouring was entirely absent, and they were of a dull buff or yellowish hue. The latter particles did not, in other respects, in any way differ from the most highly coloured particles in appearance. In some cases, as fractured specimens showed, the particles were solid and seemingly homogeneous throughout, but in others they appeared to contain a central cavity—an appearance which, as will appear farther on, was not a deceptive one.

When examined under comparatively high powers, from 400 to 1,500 diameters, they appeared to be composed of a finely molecular material. In some instances they presented a homogeneous aspect, but in others they had more or less of a cellular appearance, being marked out into areas by obscure double lines. This appearance was, in some cases, not dependent on any true cellular structure, but was due to the existence of irregular fissures running through the substance of the particle and extending from the central cavity when the latter was present. In other instances, however, the phenomenon appeared to be of a different nature, and the structure of the particles seemed yet to retain the traces of the fat cells out of which they had been formed.

Beyond these characters nothing could be ascertained regarding the nature of these particles by microscopic examination alone, and recourse was accordingly had to the use of reagents. In working at the chemistry of the subject, we had the great benefit of the advice of an accomplished chemist, Mr. C. H. Wood, the Quinologist to Government, who not only suggested the use of various tests, but also tried some of them for us himself. We shall now give an account of the effects produced by the

various methods and reagents employed, and shall subsequently state the conclusions at which we have arrived in regard to the nature of these curious bodies. It was very easy to procure large numbers of the particles free from other materials, as, owing to the fact that their specific gravity is very high, they were rapidly deposited when shaken up with water and allowed to subside.

1. *Liquor Potassæ.*—This at once changed the rosy colour to a dull buff yellow, but produced no further effect, even when the particles remained for prolonged periods immersed in an excess of the re-agent. When, however, a concentrated solution was resorted to, the particles were slowly dissolved.

2. *Liquor Ammoniæ.*—The effects produced by this re-agent were precisely similar to those of the liquor potassæ.

3. *Hydrochloric Acid.*—This when dilute produced no effect, save somewhat brightening the red colour in some instances. When applied to specimens which had been previously treated with potash or ammonia, the red colouring was in general at once restored, and the processes of discharge and restoration of colour could be frequently repeated by means of alternate applications of the alkaline and acid re-agents.

4. *Nitric Acid.*—The effects of this when dilute were precisely similar to those of the previous re-agent.

5. *Sulphuric Acid.*—This when weak acted similarly to the other acids. When strong, it broke up and partially dissolved the particles.

6. *Acetic Acid.*—The action of this was precisely similar to that of the weak mineral salts.

7. *Chromic Acid.*—This at once destroyed the colouring of the particles on coming in contact with them. A development of bubbles of gas then, generally occurred within the substance of the particles, more especially in those containing a distinct cavity in their interior, and the formation of such bubbles, followed by their gradual expulsion through fissures, where such were present, continued for some time. Short tubes and globules resembling myeline were then gradually given off from the surface of the particle, and, growing outwards, ultimately were detached from it. After this the mass became more and more obscure and dimly molecular, and finally remained as an indistinct molecular flake.

8. *Liquor Iodi.*—This produced no effect, save somewhat browning the bright rosy tint of the particles where it came into contact with them.

9. *Benzene.*—Some particles having been carefully prepared by successive washings with water, alcohol, and ether, were then subjected to the action of boiling benzene for more than half an hour. Their colour, which had been partially discharged by the action of the alcohol and ether, entirely disappeared, and they assumed a somewhat fatty aspect. They were, however, otherwise unaltered, and showed no tendency towards solution.

10. *Chloroform.*—This produced much the same effects as benzene.

11. *Sulphide of Carbon.*—The action of this resembled that of the two previous re-agents.

12. *Heated Oil.*—Prolonged immersion in olive oil at 212° F. produced no effect on the particles, save perhaps a slight alteration in their colour.

13. *Heat.*—On placing particles on a capsule or sheet of platinum and exposing them cautiously to the heat of a spirit lamp, they were found to become blackened almost immediately, their surfaces assuming a jet black colour and glistening appearance, as though they were partially melted. At the same time their outline frequently became somewhat irregular, and a distinct but very transitory smell resembling that of burned feathers was given off. On subsequently applying the blow-pipe and subjecting them to a bright red heat for a moment, the particles were found on examination to have become partially white—in many cases almost entirely so—a mere sprinkling of minute black points remaining on the surface. When still further heated, all blackness finally disappeared, and the particles were either pure white or partially white and partially rusty brown, in colour. Though possibly somewhat smaller than they had been previous to exposure to heat, they yet retained their characteristic forms almost intact, and by careful manipulation could be removed entire and submitted to microscopic examination. They were then found to consist of shells or skeletons of inorganic matter, the particles of which had a more or less crystalline aspect.

Their outlines, and general forms under the microscope too, were very frequently almost identical with those of the original red particles. The material of which they were composed was either entirely colourless or more or less stained, of a bright rusty brown or yellowish tint. When the former was the case, they were entirely soluble in weak acids, the solution varying in rapidity in different instances. In some cases it was accomplished quietly and without any evolution of gas, whilst in others effervescence occurred in various degrees. When, however, any rusty brown matter was present this remained in great part unaffected by dilute acids, but was readily soluble in strong hydrochloric acid, and if ferrocyanide of potassium were then added to the solution an immediate development of blue colour took place. The presence of considerable quantities of iron in the ash of the particles may perhaps be even more strikingly demonstrated, in many instances, by treating the skeletons of the particles with weak acid whilst still on the platinum, and then adding the ferrocyanide, when each particle immediately becomes of a deep Prussian blue.

Such have been the results of our investigations into the structure and composition of these peculiar bodies, and we have now to consider the question of their real nature. Save in regard to some vague points of form, they present nothing which can in any way suggest that they are of a vegetable or parasitic nature. Even in regard to form, too, they show nothing which may not frequently be found in concretions of various kinds; for, although some of the appearances may in some degree appear to suggest a process of multiplication by cell division, they may all be readily accounted for by mere mechanical processes of aggregation and fracture. Taking everything into consideration,

we have no hesitation in affirming them to be mere concretions, containing varying proportions of mineral matter in the form of phosphates and carbonates, and, in many cases, combined with a considerable quantity of iron. The presence of carbonates, phosphates, and of iron was clearly demonstrated by the action of re-agents.

To what their brilliant rosy coloration is due, we are unable satisfactorily to determine; but, as we shall hereafter see, the fatty matter of the degenerate tissues in the pale variety of the Madura disease has, under certain circumstances, a tendency to give rise to the development of such colouring. The red colouring is, moreover, not an essential character in the concretions, for, as previously mentioned, numerous specimens occurred of precisely similar nature to the most highly coloured ones, save in being of a buff or yellowish hue in place of bright carmine, whilst many other intermediate forms were present showing various degrees of staining. The specimen in which they occurred was preserved in strong glycerine, and there appeared to be a gradual but considerable increase in their numbers whilst it was kept under observation. In studying the conditions under which a development of red colouring matter occurs in connection with the fatty products of the ochroid variety of the Madura disease, we have observed that one of them appears to be the existence of more or less decided acidity, and it is noteworthy that in the present instance the glycerine was distinctly acid in reaction. The results of attempts at cultivation of the red particles will be given subsequently, but in the meantime we would repeat that they appear to us to be mere concretions, probably formed from the degenerated tissues—the proportion of constituents furnished by the latter varying in different instances. Possibly they owe their red hue to a substance analogous to the colouring matter of the blood—just as other pigmentary substances are believed to do.

CHAPTER VI.

A DESCRIPTION OF SPECIMENS ILLUSTRATIVE OF THE DARK VARIETY OF THE FUNGUS-DISEASE OF INDIA.

HAVING given a minute description of several examples of the pale variety of the fungus-disease, we now proceed to give a similar description of a few typical specimens of the dark variety. Instead, however, of giving a full account of the peculiar substance which is characteristic of all of them, we shall defer the details of the more minute investigations of it until the general appearance of the specimens has been described. This will economise space without sacrificing exactness, for this dark substance does not materially vary in the different specimens.

SPECIMEN I.—A glance at the accompanying sketch of a longitudinal section of the left foot of a native will convey a more accurate conception of the state of the tissues in this disease than any verbal description. An ordinary scalpel was made

to pass through the tissues from the inter-digital space between the second and third toe, in a line towards the middle of the tibia and through the centre of the ankle joint. The scalpel passed readily through all the tissues, except the tibia and the portion of the astragalus articulating with it. The foot is enlarged in all directions; the toes are turned upwards in the same manner as may be observed in the Specimen in Plate I, delineating the pale variety; and there are several openings on the surface which may generally be found to be continuous with a cavity in the tissue below. Some of the orifices are plugged, more or less completely, by irregular little aggregations of black substance which can be picked out. On examining the section, the outlines of the tarsal bones cannot be made out; but as the figure shows, the bones occupy an irregular space, perforated by numerous excavations in all directions. The middle portion of the metatarsal bone, exposed by the section,

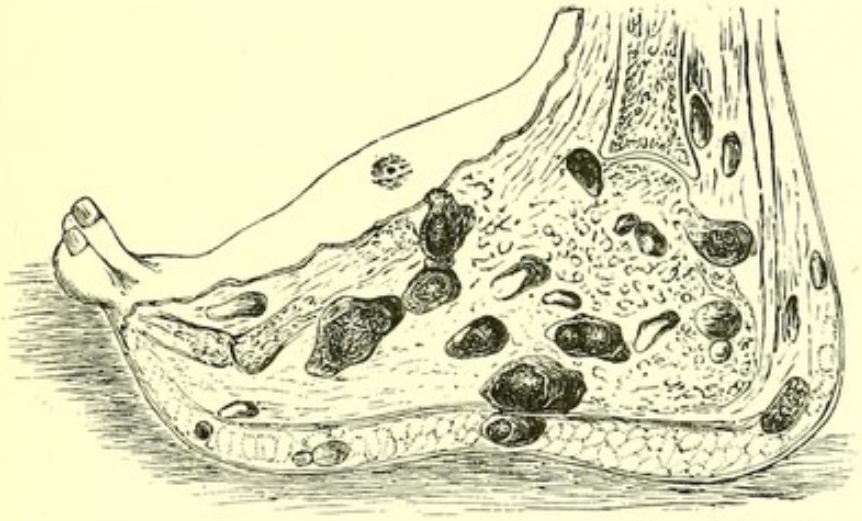

Fig. 9.—A section through an affected foot showing numerous cavities with dark masses *in situ*. Isolated areas in the subcutaneous fat of the sole are also distinguishable.

is found to be broken down, and the arch of the foot completely given way, so that the natural direction of the longer bones of the foot and the toes has become altered. Between the first phalanx of the second toe and its corresponding metatarsal bone, a new articulating surface has been formed on the dorsal surface of the latter.

The cavities were in some cases isolated, but in others they communicated by means of one or more channels with adjoining cavities, the cavities and channels being everywhere lined by a more or less dense, smooth membrane of tough, fibrous tissue. The cavities are of very unequal size; they vary from being just large enough to contain a pellet of small shot to being sufficiently capacious to hold a bullet with ease. They almost invariably contain irregular lumps of a dark granular substance, which, more or less completely, fills the cavities and the channels continuous with them. Frequently, however, the dark material occupies but a very small portion of the cavity, even though the cavity be completely isolated. The fatty padding of the sole of the foot appeared to be normal, but in two or three places

small groups of the lobules have been replaced by cavities containing the dark material.

Numerous fragments of tissues immediately adjoining the cavities were subjected to careful microscopic examination, with results as follow :—

(1) Muscular tissue from various parts of the foot. For the most part in a tolerably normal condition ; at one spot only could distinctly disintegrated fibres be distinguished. All the samples were subjected to the influence of various re-agents, including the free use of liquor potassæ, but nothing peculiar could be distinguished.

(2) The membranous lining of the cavities and channels or sinuses. This consists of ordinary fibrous tissue, and microscopically is in no way to be distinguished from similar tissue lining cavities in other abnormal conditions. Such specimens were purposely obtained with a view of instituting comparisons. Frequently reduplications of fibrous tissue form septa, so as to separate a cavity into partially distinct compartments. Neither could we distinguish any unusual appearance in the tissue forming these septa, although they were necessarily in immediate contact with the dark material in every direction. Every re-agent we could think of was resorted to here also.

(3) Small fragments of bone from immediately adjoining the excavated parts, forming in fact the osseous boundary of the cavities, were subjected to the action of potash under the microscope. The granular matter filling up the interstices of the bony tissue was rapidly disposed of, but no new structures were brought to light, although the opened-out condition of the cancellated tissue was highly favourable to accurate inspection.

The nature of the dark material will be considered further on in detail ; it will be sufficient here to state that, after subjecting fragments of it to more or less prolonged action of liquor potassæ, numerous filaments and cellular bodies were brought into view.

Specimen II (Plate XXVII, Fig. 2).—This preparation consisted of the right heel and ankle—amputation having been performed through the lower fourth of the tibia and fibula. The fore part of the foot had been removed. It was in an excellent state of preservation. It had been put up by Dr. Mark Robinson, of Madura, in brine, and forwarded to us without delay, as a specimen of the affection which, although possessing distinct black granules, was not one in which the tissues are extensively diseased.

Dr. Robinson also favoured us with a note as to the condition of the limb before amputation. His words are :—"Right ankle much enlarged, and on both the inner and outer side numerous sinuses—a slight elevation round each opening. A thin yellowish discharge exuded from these openings : no dead bone to be felt by probing. He was unable to walk on this foot.

"After removal of the foot a cut was made through the soft tissues of the ankle, and it was found that they were infiltrated with a yellowish gelatinous substance :

the darker patches containing small black granules, the muscular tissue very dark in colour. No section was made through the bones, but they did not appear to be diseased. In the Tibio-astragaloid joint there were some flakes of lymph, but the articular surfaces were smooth and bright."

The lower part of the tibia was softened and the cancellated tissue pinkish, especially beneath the cartilage. The shaft was dense, normal in texture, and apparently healthy. The structure of the os calcis and the astragalus was generally very dense. The posterior portion of the astragalo-tibial articular surface was excavated and occupied by masses of black substance; there was also a cavity in the anterior part of the os calcis of the size of a small bullet, which was bounded by some very open bone texture. The cartilaginous portion of the os calcis was also eroded and the space occupied by black matter; but the cartilage was not affected to the same extent as the bones, so that projecting portions of it bridged over the hollow occupied by the black matter.

The remaining tarsal bones were softened so as to be cut with ease with a scalpel, and in some places the texture was much softened and opened out.

The pad of fat usually found between the tendo Achilles, and the posterior surface of the tibia surrounding the deep tendons, was completely converted into a mass of black matter continuous with that in the astragalus and os calcis. The deep tendons, although surrounded by this material, were unaffected and perfectly healthy.

The muscular tissue also was wholly unaffected.

There were various mammillated openings leading into cavities containing black granules on the surface of the foot and ankle.

On making sections through the skin of the foot, numerous perfectly isolated collections of black granules like grains of coarse gunpowder, were found to occupy the loculi in the subcutaneous cellular tissue usually occupied by fat. In some an entire lobule of fat appeared to have been converted into a black mass and surrounded by a distinct firm capsule, and in others the lobules were only partially affected—a few black grains, each invested with a capsule, lying among the clusters of cells of the unchanged fatty tissue. This condition will be more minutely described in a subsequent chapter (Chapter VII, page 366).

SPECIMEN III.—A hand amputated about 3 inches above the radio-carpal articulation. The cut ends of the two bones of the forearm are unaffected. There are several openings on the dorsal surface of the hand—front of the wrist, on the ball of the thumb, and a few along the line of the superficial palmar arch. The hand is swollen and peculiarly distorted, as may be seen from the engraving (Fig. 10). The fingers are not themselves distorted, but are flexed and turned outwards owing to the action of the flexor muscles being continued subsequent to the disorganisation of the carpal bones. The nails are unaffected.

A section was made by means of a scalpel in a line extending from the space between

the junction of the second and third phalanx to the point of juncture of the ulna with the radius at the wrist. The knife passed readily through the os magnum, the semilunar bone, and the outer articular edge of the radius. The distal end of the os magnum was found to be completely disintegrated, and between it and the upper end of the second metacarpal bone was lodged a mass of dark-brown substance, the brown tint predominating towards the centre, where, it might almost be described as presenting a dark-red tint. Several other aggregations of dark material were found lying between this mass and the flexor tendons.

In the subcutaneous tissue along the back of the radius, there were several isolated little cavities, or cysts, containing aggregations of a cheesy, fatty substance mixed with black granules. They could be picked out separately for examination; in the dark masses filaments could be distinguished after prolonged immersion in potash; but in the yellowish, roe-like particles, picked out of the same cavities and similarly treated,

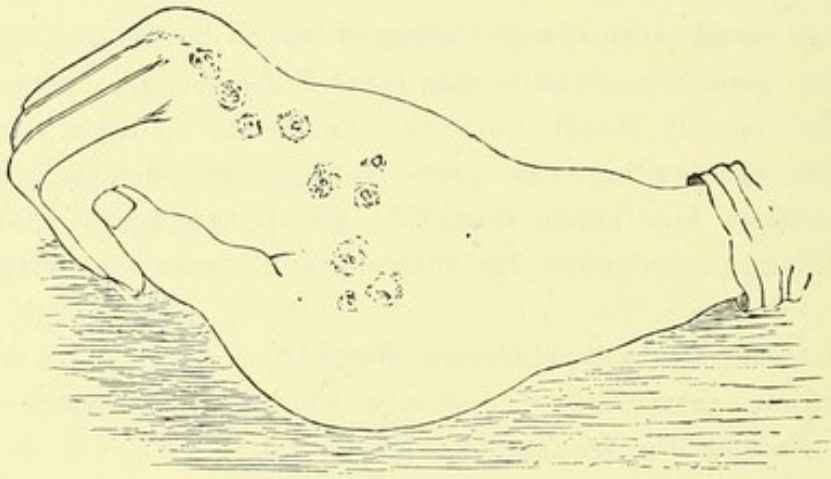

Fig. 10.—Peculiar distortion of the Hand in a specimen of the Dark variety of the affection.

no such filaments could be demonstrated when the particles were carefully selected. These isolated cavities were limited to the subcutaneous areolar tissue between the extensor tendons and the skin of the back of the wrist.

SPECIMEN IV.—Another hand, also amputated a short distance above the wrist joint. The hand was considerably thickened and the wrist swollen: the palmar surface was puffed up, and numerous openings both there, on the dorsal surface, and between the fingers, communicated with a large cavity within. A scalpel was carried longitudinally through the middle of the hand, the bones that still remained being readily divided, as well as the end of the radius for a short distance. All the carpal together with a great part of the metacarpal bones were destroyed,—the basal half being the portions in the latter most affected. The phalanges were somewhat softened, but were not eroded, and contained no black matter. The metacarpal bone of the third finger was eaten out and rough, the destruction having proceeded so far as to separate the bone into two rough, irregular fragments. There was not much thickening on the uneroded surfaces. The cavities in the bones were not lined, and the bone presented the appear-

ance of ordinary caries. The cancellous tissue of the end of the radius, and of such portions of the carpal bones as remained, was very porous and widely opened out. Where, however, the cavities were located among the soft tissues they were lined by a membrane. The tendons were not affected.

The large cavity, referred to as communicating with the surface by means of various channels, occupied the space normal to the carpal bones, and was filled with fragments of these bones mixed with black granular material, which also extended into the channels alongside of the tendons.

The black material, after prolonged immersion in liquor potassæ, was found to contain filaments, but they were by no means so plentiful as ordinarily observed.

Not the slightest indication of any such filaments could be demonstrated in any of the parts—recognisable as tissues—whether diseased or healthy.

SPECIMEN V. (Plate XXVII, Fig. 1).—This was a portion of the left foot of a native which had been removed by a Chopart's amputation. There were several openings, with elevated margins, both on the dorsal and plantar surfaces of the foot, out of which dark granules could be picked. There was scarcely any thickening of the tissues of the dorsum.

The preparation was divided longitudinally into four segments. The appearance presented by the first section is delineated at Plate XXVII: the scalpel is seen to have been carried through the middle line of the bones of the second toe. The central portion of the second metatarsal bone was, in great part, occupied by a dark-brown, spherical mass about an inch in diameter, shaped something like a potato and presenting a slightly radiating, finely striated appearance on section. It was moulded to the cavity in which it was lodged, and its projecting nodules fitted accurately into adjoining cavities in the surrounding tissues. The upper portion of the bone was curved, its tissue thickened and hardened, and the lower portion fractured, a splinter being carried in front and behind the dark globular mass, thus aiding in the formation of the cavity. The latter communicates with both the dorsal and plantar surfaces of the foot by means of irregular channels containing small black masses. The middle cuneiform bone was somewhat softened below.

There was another large cavity (visible in this line of section) situated somewhat behind the one just described and above the plantar fascia. It also contained dark tuberculated masses, and opened into several small cavities which communicated with the surface on the sole of the foot. There were other cavities of smaller size.

The second line of section was carried from behind forwards through the middle of the cuboid bone, the base of the fourth metatarsal, and the line between the latter bone and the third metatarsal. In this section the outer boundary of the large cavity was distinguished; it consisted of a delicate fibrous membrane just sufficient to partition off the cavity from another group of cavities and channels. This group appeared to have originated with a cavity in the third metatarsal bone. The base of this bone was intact at its articular surface, and for about a third of an inch forwards, but then became

covered with rough, warty nodules of hard bone extending along the entire length of the shaft, the sclerosis being specially marked towards the basal extremity of the bone. Its under and inner surfaces were involved in the large cavity, and were more or less scooped out. Like the second metatarsal this bone was also arched; the phalanx of the third toe was articulated on to the dorsal aspect of the corresponding metatarsal bone; the toe was consequently directed upwards.

The third line of section was carried through the scaphoid, internal cuneiform, and the longer bones of the great toe. There were other centres of disease here also. A similar excavation had taken place in the metatarsal bone of this segment, and the cavity was occupied by a dark globular mass. As in the other bones, the upper surface of this was likewise curved, and the texture extremely dense, and its outer aspect presented a hard nodulated surface. The bones of the phalanges were unaffected. The scaphoid and cuneiform bones were reddish in the centre, as if from blood staining; the colour faded on exposure to air. Nothing peculiar could be detected in the reddish substance when examined under a microscope.

The tubercles along the affected metatarsal bones consisted of small, hollow, closed cavities, which could be shaved from the surface of the bone. Some were rounded elevations, like miniature limpet shells; others were elongated and even tubular. Their osseous walls were thin and very dense, and sometimes projecting spicules of bone were given off from them internally. Their contents consisted mainly of fat with a mixture of fibrous and connective-tissue corpuscles.

The black material was microscopically identical with the similar substance in other preparations—that is to say, it contained the usual filaments, but none of these could be found in either the muscular, osseous, or fibrous tissues of the surrounding parts, although carefully searched for by every known method.

CHAPTER VII.

PHYSICAL CHARACTERS AND RELATIONS TO SURROUNDING TISSUES OF THE BLACK MATERIAL FREQUENTLY ASSOCIATED WITH THE FUNGUS-DISEASE OF INDIA.

It must strike even the most casual reader, that the occurrence of these peculiar lumps of black substance in the midst of the tissues referred to in the last chapter, and especially in connection with Specimen V (page 365), is very remarkable; and no one will wonder that it has been found very difficult, or rather impossible, satisfactorily to account for their presence. It will have been observed that these masses have been found, speaking generally, under three conditions: (1) in small completely isolated cavities; (2) in large cavities more or less accurately moulded to their walls; (3) as broken fragmentary masses lodged in irregular cavities and channels communicating freely with the surface.

As there is less disturbance of the surrounding tissues where the dark masses are found enclosed in minute cysts, they will present fewer complications, and are therefore more instructive than the large tumours described in connection with the last specimen, with all the extensive alterations which had taken place in connection with them; in other words, the significance of the presence of the larger masses will become more evident after examination of the smaller ones which are found under less complicated conditions.

Whilst describing specimens of the pale variety, Chapter III (Specimen IV, page 351), and Specimens II and III (pages 362, 363) of the dark variety of the disease in the last chapter, attention has been drawn to the fact, that certain of the fat lobules in the subcutaneous tissues had undergone some alteration; whereas other, immediately adjoining, fat lobules were apparently in the normal state, or only altered to a trifling extent. Some of these altered lobules which have been found in preparations affected with the dark variety of the disease have contained dark granules. The accompanying woodcut of a dissection under a low power of a little group of this kind will more clearly convey our meaning. A little of the subcutaneous tissue from over the ankle joint of Specimen II (page 362) was removed and spread out under the dissecting microscope for the purpose of examining a minute dark speck in the midst of what seemed to be normal adipose tissue, which seemed likely to prove to be the peculiar dark substance found in connection with the malady, enclosed in a capsule. This encysted little mass was lying between two somewhat hardened, otherwise normal, healthy, encysted aggregations of fat, as delineated in the engraving (Fig. 11), in which the lining membrane surrounding the dark material is represented as torn open. This capsule was, however, more dense than the capsules surrounding the ordinary fat masses, although it resembled them in general appearance. Microscopically it consisted of connective tissue, but with a smaller proportion of elastic fibres than that in the normal capsules. It was easily teased out. The material enclosed by the capsule consisted of an aggregation of smooth, black, ova-like particles, each of which was contained in a separate fibrous capsule similar in structure to the general investing capsule, so that the bodies were, although closely aggregated, quite distinct from one another. The black matter could be readily pressed out from the capsules, leaving the latter more or less empty.

Fig. 11.—Three encysted masses of altered adipose and connective tissue. The centre one torn open and showing the characteristic black granules... × 6.

Whatever may be the nature of the agent which determined the formation of this minute saccule of dark granules in the midst of saccules of fat cells, it can scarcely be doubted that it must be essentially identical in character with the agent which determined the formation of the large nodular masses in the midst of the bones and areolar tissue of the same preparation—the darkened material being in the two cases of precisely similar composition.

There are moreover, many gradations in the character and extent of the changes between the two extremes just referred to. The accumulation of granules may considerably increase in size and the fibrous envelope become stronger (Fig. 12); this condition may become more and more marked, until eventually large portions of the ordinary tissue of a part become replaced by the black masses and their tough fibrous receptacles.

The physical characters of this peculiar dark substance are briefly these: The colour varies from brownish-yellow to reddish-brown and black. The consistence of the different masses also varies somewhat, apparently according to the relative proportion of unchanged fatty material associated with it, upon which also the variations in colour appear to depend. The specific gravity also varies—generally it may be referred to as being somewhat greater than water. Some of the lumps, however, sink almost as readily as a stone when placed in this fluid. We have never seen examples of the substance that would float either in spirit or in water.

Fig. 12.—A fragment of the affected tissue from a foot showing the thickened fibrous septa forming the cavities, some of which are seen to contain the black substance: a few particles of the latter are seen below, out of the cavities.

When placed under the blow-pipe it burns into a flame, giving off fumes suggestive of burnt feathers. After being subjected to this heat for some minutes, a very light, dirty-white ash remains, portions of which under the microscope present a reticulated semi-cellular aspect. The ash dissolves slightly in water, and the solution yields a strongly alkaline reaction to test paper. The greater portion of what remains undissolved by the water is speedily dissolved by dilute hydrochloric acid, and the solution gives with sulphuric acid, the characteristic reaction of a lime compound.

A fragment of bone from the same foot was similarly burnt, and the ash was found to yield very similar reactions, except, perhaps, that the solution of the ash in water was less alkaline to test paper.

The dark material is insoluble in water and spirit, and only sparingly so in ether, but is almost completely soluble in potash. Weak acids do not materially affect it.

Since these remarks were in type we have received a note from Mr. C. H. Wood, at present the officiating Professor of Chemistry at the Medical College, and whose

assistance we have already had occasion to acknowledge in this Report, giving a brief account of the result of examinations of fragments of the black substance which he kindly undertook at our request. According to Mr. Wood the material yielded—

Moisture (by drying at 100° C.)	76·7
Mineral matter	1·4
Organic matter (containing a trace of fat soluble in ether) ...	21·9
	100·0

"In the dry state," Mr. Wood writes, "it is quite brittle and may be powdered. The ash is of a red colour from the presence of oxide of iron, but consists chiefly of calcium phosphate. The substance is unaffected by boiling water or acetic acid. Dilute hydrochloric acid gradually extracts a little colour from it, but the alkalis are its only solvents. It forms with potash a brown solution and softens in ammonia undergoing partial disintegration. In its chemical characters this substance somewhat resembles elastic tissue."

The solution of the black material obtained, after subjecting the substance to prolonged ebullition in distilled water, does not yield any characteristic appearance when examined with the spectroscope; nor does a similar solution when treated with sulphuric acid. When, however, some of the material has been dissolved in caustic potash and examined with the spectroscope, it is found that the solution obscures the violet end of the spectrum as far as about the middle of the green—the violet and nearly all the blue being completely absorbed. Blood treated with potash yields a very similar spectrum, but we could not make out the absorption bands of hæmatine in any of the numerous solutions in which the darkened substance had been macerated.

It is the microscopical appearance of this material, however, which presents the most marked peculiarity; that is to say, its microscopical appearance after a more or less prolonged immersion in liquor potassæ. The most satisfactory method of procedure is to crush a lump of the material about the size of a hazel nut, and place it in a test tube with about half an ounce of a strong solution of potash: when set aside for three or four days, it will generally be found that the granular consistence of the substance has disappeared, the fluid has become of a dark colour, which subsequently passes into a pale sherry colour, and that a small flocculent sediment has subsided in the tube—not more than one-fiftieth, however, of the amount of material introduced. A little of this should be carefully transferred on to a drop of water placed on a glass slide, very gently spread out by means of needles, a covering glass applied and the slide examined under a power of from three to five hundred diameters.

The woodcut on the following page very accurately represents what will, in all probability, be observed (Fig. 13), *viz.*, numerous branching filaments, septate and perfectly translucent, mixed to a greater or less extent with empty looking cellular bodies. Morphologically

these filaments are not distinguishable from those of fungi, but they do not appear to contain any plasma.

They are capable of withstanding the influence of a large number of powerful re-agents as the following list will indicate :—

Potash has no destructive influence upon the filaments, or on the capsules associated with them.

Carbolic Acid and Alcohol.—No effect after 15 minutes, nor did the subsequent addition of potash alter the appearance of the preparation.

Bisulphide of Carbon.—No effect.

Benzene.—Filaments were boiled in this fluid for several hours, and also in *chloroform*, without producing any marked change.

Olive Oil and Animal Fat (butter).—Various specimens were boiled in these

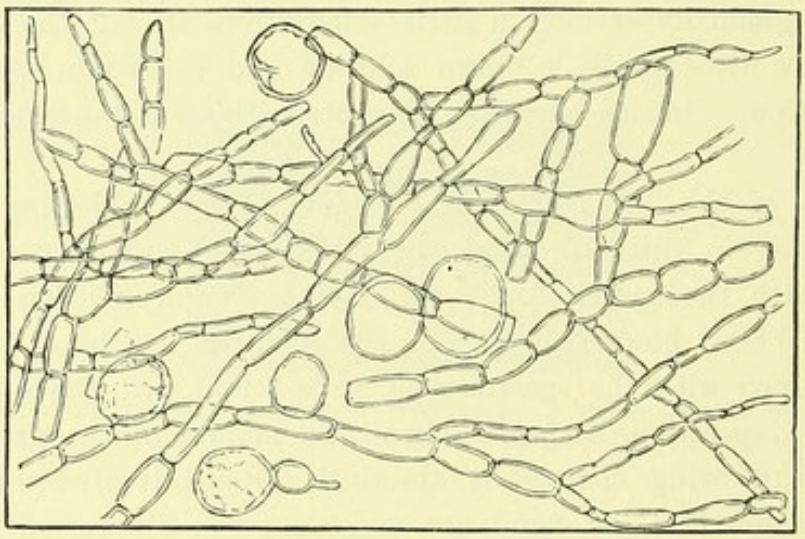

Fig. 13.—Fungoid filaments and capsules obtained after prolonged maceration of the black substance in caustic potash. × 500.

substances without result, except that, eventually, the filaments became charred owing to the high heat to which the oils had been subjected. Some specimens were subjected to being treated in oil for 12 hours over a water bath.

Tincture of Iodine stains them yellow, and sometimes appears by its reaction to suggest that the tubes and cells are not void of plasma, as they appear to be prior to the addition of the iodine. It never communicates a blue tint to any of these structures —not even when combined with sulphuric acid.

Sulphuric Acid destroys the filaments, so does concentrated hydrochloric acid, perhaps owing to the presence of sulphuric in it.

Oxalic Acid also, when concentrated, causes the filaments to disappear.

Carmine.—After prolonged immersion in an ammoniacal solution of this material the filaments and cells become stained.

Filaments of various fungi, when treated with the foregoing re-agents, were found

to manifest pretty much the same properties as the filaments above referred to as having been obtained from the dark substance after maceration in caustic potash.

Occasionally particles are observed in the field in connection with preparations of the black material, which readily strike a blue or dark-blue tint on the addition of iodine; but we have not been able to satisfy ourselves that such starchy compounds had not been derived accidentally—from poultices and what not—so that we are not disposed to lay any special stress on the circumstance.

The only other material which the microscope reveals worthy of special mention in connection with this dark substance, as far as we have been able to see, is the more or less marked presence of black pigment-particles which may frequently be distinguished among the filaments after maceration in the potash solution. These particles sometimes appear as if deposited within the filaments, and occasionally the filaments may be observed to manifest a distinct pigmentary staining. So that, although the alkali may dissolve the greater portion of the pigment in the substance, some of the pigmentary granules remain unaffected, as is the case with the black pigment found in animal tissues generally.

CHAPTER VIII.

CULTIVATIONS OF THE VARIOUS MORBID PRODUCTS OF THE DISEASE.

HAVING now given an account of our investigations into the nature of the changes and degenerations caused by the disease and the characters of their morbid products we shall next proceed to state, briefly, the results of our attempts at cultivations of these products. In doing this we shall in some degree depart from the order which we have hitherto followed in the consideration of the different forms of the disease; for it appears to be advisable to consider those cultivations in which the material experimented with contained distinct fungoid elements, before those in which there was no evidence of the presence of any such bodies.

In undertaking cultivation-experiments of this character, the principal difficulty usually present consists not in selection of ingredients favourable to the growth of the object under observation, but in the isolation of the latter. To follow the growth of a single spore or a speck of plasma may seem a very simple matter to such as have never undertaken such an experiment, but the task is in reality very difficult if the germ experimented upon be given a fair chance of growth—at least as far as light, heat, air, and moisture are concerned. The appliance which we have devised, and for some time adopted, to meet this difficulty, is very simple, and may be constructed by any one desirous of working out for themselves problems of this character. A glance at the woodcut on the following page will be sufficient to convey a clear conception of its construction. (Fig. 14.)

It consists of an ordinary glass slide 3″ × 1″, with a ring of bees' wax (softened by the addition of a little oil) pressed on its surface towards the middle. Intervening between the wax and slide—clamped by it, is a narrow slip of blotting-paper; and above the wax a thin cover-glass is placed with a drop of fluid containing the spore or germ to be watched. The preparation will now be hermetically sealed except at the spot where the blotting-paper is inserted, the latter serving as an excellent channel for the air and moisture necessary to the perfect growth of the object under cultivation. There is no danger of dust being introduced, and the gases which the nutritive fluid may generate can readily escape.

A.—Cultivations of the Black material from the second form of the Madura-Disease.

The materials employed in these experiments were obtained from various specimens, and consisted in some instances of portions of the black matter which had been discharged from the tissues previous to the removal of the affected extremities, and which had been preserved by being simply dried. In other cases the material was obtained from specimens which had been preserved for longer or shorter periods in

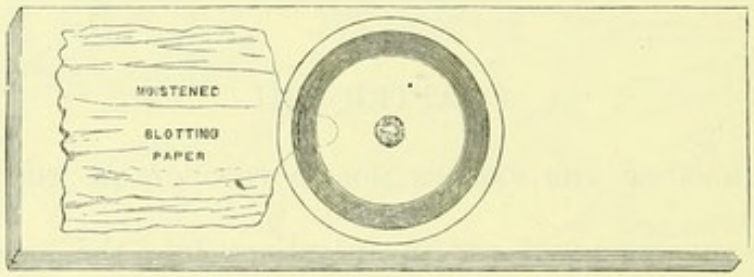

Fig. 14.—A growing-cell adapted for supplying the preparation with moist-air.

alcohol, glycerine, and other preservative media. The following may serve as examples of such cultivations and of the results obtained from them.

Cultivation I.—Portions of black matter, discharged from the foot previous to amputation in a case of the disease, and which were subsequently dried, were set in some freshly prepared rice-paste beneath a bell glass. The cultivation was commenced in the month of April.

Forty-eight hours after it had been set, the cultivation was everywhere covered with a dense crop of *Mucor*, bearing an abundance of ripe, black sporangia. At various points in the paste, patches of a greenish discoloration had appeared; and in one place there was a faint indication of a pinkish tint present. As however appearances of a similar nature were also present in a simultaneous cultivation of pure rice-paste, and were there associated with the occurrence of changes and developments precisely similar to those here present, the coloration being moreover much more distinctly marked, a fuller description of them is deferred until the particulars of that cultivation are given. There were, in addition, several patches of young *Aspergillus* heads of a white colour. During the next few days there was a rapid increase in the growth of *Mucor*, the loose

filaments of which obscured the surface of the paste with the other fungal elements occurring on it.

Six days after the commencement of the cultivation, this loose overgrowth was cleared off and a luxuriant crop of *Aspergillus* was exposed to view. This consisted of two species of the above mentioned genus—the first, the common yellow *Aspergillus*; the second, another species, of very frequent occurrence in Calcutta, in which the heads are of a rich brown colour and the spores of very minute size. The latter arise from sterigmata, which are not, as in the yellow species, inserted directly on the globose extremity of the fertile filament, but are arranged in fours on the broad extremities of large cuneiform processes intervening between them and the latter. A dense felt of mycelial filaments and fallen spores covered the surface of the paste, and on carefully removing this the black particles were found apparently entirely unaltered.

Immediately around some of them the substance of the paste was of a brownish orange hue, but no peculiar organisms could be found in such places, and there was no evidence of germination or growth of any kind from the black matter. This staining may have been due to a certain amount of solution of the colouring matter of the particles; but even this is very doubtful, as similar staining was frequently observed in cultivations of pure rice-paste to which no black particles had been added. The felt of mycelium having being removed as thoroughly as possible, the specimen was again set aside. It soon became covered anew with yellow and brown *Aspergilli*, together with a smaller regrowth of *Mucor*, whilst patches of *Penicillium glaucum* also began to make their appearance here and there.

Subsequently one or two patches of dull reddish discoloration appeared, consisting of a granular basis through which colourless mycelial filaments ramified, but they were of the same nature as those which occurred in other instances on pure rice-paste and showed no signs of being in any way organically connected with the black particles. The cultivation was kept under observation for three weeks, and at the close of that time was almost entirely covered with a dense layer of *Penicillium glaucum* with a small quantity of *Mucor* still occurring here and there. The black particles showed all their characteristic features under microscopical examination, and afforded no evidences of any attempts at germination nor any signs of vitality on the part of the fungoid elements present in them.

CULTIVATION II.—Contemporaneously with the above cultivation another was carried out in which a portion of the same rice-paste was set beneath a separate bell glass without the addition of any foreign matter.

This also became rapidly covered with a crop of *Mucor*; ripe fructification however not appearing quite so rapidly as in the previous case. The substance of the paste forty-eight hours after the commencement of the experiment was everywhere discoloured by dull green patches, whilst here and there minute points of brilliant carmine-pink were present. The latter were carefully examined with the following results. The masses of pink matter were mainly composed of a gelatinous basis full of minute particles,

and both of these elements were of a bright rosy colour. Where filaments of mycelium penetrated such masses, their contents also were frequently of a similar bright pink, and this coloration of the protoplasm in many cases was not confined to those portions which were absolutely within or in contact with the coloured material, but continued for some distance farther, rendering the affected filaments very conspicuous, as pink or carmine bands among the surrounding colourless mycelial and bacterial elements, and gradually fading off so as to leave them in their original condition.

The pink colouring was not confined to the living bodies present in the cultivation, but also affected portions of the tissue of the rice grains in the paste. The pink colour was confined to the protoplasm of the mycelium and did not affect the walls of the filaments, for, when the former was caused to contract under the influence of re-agents, the latter, which were then more or less widely separated from it, were seen to be perfectly colourless.

These patches of pink colour were of a very transitory nature; they had entirely disappeared in forty-eight hours after they were first observed, and there was no recurrence of them afterwards, although the cultivation was kept for several weeks under observation. The *Mucor* never showed such a luxuriance of growth and fructification in this as in the former cultivation, and the paste ultimately became covered with a dense coating of *Penicillium glaucum*, and of a form of *Helminthosporium* with a dark brown mycelium. A few orange coloured stains, like those in Cultivation I, also appeared on the paste, but these showed no special peculiarities on microscopical investigation.

It is needless to repeat the details of numerous other experiments on cultivation of the black masses, as the results were in all cases essentially similar to those described above, and this both where the materials had and had not been subjected to preservation in alcohol, or other preservative agents.* The only variations observed concerned the species of common moulds which were developed in different instances, and the relative proportions which the individual species bore to one another in the different cultivations. It may be sufficient to state that in no case did any forms of fungi or other organisms appear in cultivations in which the black material was employed, which did not also occur where rice-paste alone was employed, and that in no instance did any of the fungoid elements of the black matter exhibit the faintest indication of any tendency to germinate. On the contrary, one of the most remarkable features in connection with the cultivation was the extremely persistent and seemingly inert nature of the material, the masses being found to all appearance entirely unaltered in character and contents after weeks of immersion in paste (and at all times of the year), in which the most luxuriant development of fungi had occurred.

CULTIVATION III.—Cultivation of the black matter in water.

As the peculiar mould, characteristic of, and peculiar to, the diseased tissues, is

* When the material had been preserved in spirit, etc., it was always carefully washed and immersed in water for several days before being set in the paste.

stated to have been originally observed in a maceration of a specimen of the disease, we tried numerous experiments with a view of ascertaining whether any such development would occur in the instance of the materials at our disposal. A portion of cancellous bone, containing characteristic black masses, was removed from a foot preserved in spirit and set in water in the month of April. The water was at first, on several successive days, poured off and renewed with a view to get rid of the spirit, and when this had been apparently thoroughly accomplished, the maceration was allowed to go on continuously. The specimen was kept under observation for several weeks. No fungi were developed in connection with it, but an abundance of active and still bacterial elements soon made their appearance, and these, together with some maggots which subsequently aided them, rapidly removed all the soft tissues and oily matter connected with the bone, and left the latter and the masses of black matter behind. The black matter never showed any tendency to germinate or to be altered in any way, and on microscopic examination at the close of the experiment, presented all its characteristic features entirely unchanged.

CULTIVATION IV.—This was precisely similar in its nature to the previous cultivation, and was carried on at the same time of year.

In this case also an abundant development of *Bacteria* occurred. The soft tissues of the specimen became gradually disintegrated, and a film of a yellowish colour and considerable density formed on the surface of the fluid. This was found to consist of a dense layer of *Bacteria* and granular matter, with innumerable active and encysted specimens of several forms of ciliated infusoria. A few colourless, slender mycelial filaments were also present, and here and there were lumps or concretions of fatty matter of a distinctly pinkish tint. There were however no evidences of the presence of any peculiar algoid or fungoid organisms, and the black masses remained seemingly quite unaltered during the entire course of the experiment.

Numerous other experiments of a like nature, conducted at the same and at other seasons of the year, and with materials derived from different specimens obtained from different localities, gave similar negative results. There was a uniform and entire absence of evidence in favour of the presence of any growth of the elements contained in the black matter or of any other signs of vitality in them, and the only remarkable feature presented by the material in this, as in the former series of experiments, was its extreme persistence and apparent resistance to disintegrative changes.

Whilst, however, these experiments not only entirely failed to demonstrate the existence of any living fungoid organisms in the black matter of the disease, but even seemed to indicate that it did not form a favourable basis for the growth of extrinsic fungi, we have on other occasions frequently observed specimens of the masses become mouldy. This has occurred after the rains have fairly set in, and during periods of very damp weather. At such times there is frequently a development of a white mould on the surface of dried specimens of the material; but as this is due to the growth of the common *Aspergillus* on the surface, and not to any germination of the elements of the

substance of the masses, it is obviously a matter of no special importance or interest, save as affording a new example of the varied nature of the substrata on which this ubiquitous mould will occur.

B.—Cultivations of the Morbid products of the Pale variety of the affection.

The next series of cultivations, regarding which some particulars must be given, are those in which the material experimented with consisted of the roe-like masses and other morbid products and tissues obtained from specimens of the ochroid variety of the disease.

The cultivations of such materials on rice-paste need not be specially alluded to, as they gave results which differed in no essential particulars from those in the experiments with the black matter. Some of the cultivations or rather macerations in water, however, presented some peculiarities and points of interest.

CULTIVATION V.—Some of the cancellated tissue and oily matter were removed from the bones in a specimen described in the present report as Specimen I (page 345) of the pale variety of the disease, and set in a wide-necked bottle of water beneath a bell-glass. The water was once or twice changed at first in order to get rid of the spirit in which the specimen had been preserved and was then allowed to remain undisturbed. No noteworthy change occurred for some time. After the lapse of a fortnight the mouth and neck of the bottle were observed to have become covered with a thin layer of mould, which had also spread over a considerable portion of the surface of the fluid. It did not, however, penetrate beneath the surface, and was widely remote from the diseased tissues at the bottom of the bottle. When first observed, the mould was of a whitish and greyish tint, and consisted solely of mycelial filaments without any fructification, but subsequently the mycelium gave rise to a crop of poor, partially aborted heads of common *Penicillium* and *Aspergillus*. The bone and fatty matter at the bottom of the fluid remained to all appearance entirely unaltered.

During several weeks no further change was observed, save a gradual evaporation of the water and a proportional spread of the mould downwards over the interior surface of the bottle as the latter became exposed to the air. The fragments of tissue at the bottom now gradually assumed a distinct pale pink hue, and light flocculi of a similar colour could be seen attached to them, loosely adherent to the sides of the bottle beneath the water or forming a light deposit at the bottom. On examining this cloudy flocculent matter microscopically, it was found to be principally composed of a granular basis, which, whenever in mass, presented a distinct pink tint; whilst even the thinnest flakes of it when examined slightly out of focus were more or less characterised by a similar colour. A few mycelial filaments were also present, together with myriads of active *Bacteria* and *Vibriones*, numerous active and encysted *Paramecia*, and a sprinkling of large active *Rotifers*. All these organisms, animal as well as vegetable, were in many instances of a distinct pink colour, which was more marked, the larger the mass of the organism affected by it; and specially bright in some of the *Rotifers*.

As time went on, this pink staining continued gradually to increase in intensity, and ultimately the deposit became entirely of a dull brick-red mingled with patches of rosy pink.

The most marked changes observed by aid of the microscope consisted in a great increase in the amount of mycelial filaments in the deposit. These were found in special abundance in the flocculent patches adhering to the sides of the bottle, and where they were present in abundance the brightest rosy colour also generally prevailed. Among and attached to the filaments, in many places, numerous large cyst-like bodies were found on carefully teasing out the flocculi (Plate XXVI, Fig. 7). These were rounded, of diameters ranging on an average from $\frac{1}{250}''$ to $\frac{1}{350}''$, and in many cases were full of roundish or oval spore-like bodies of considerable size. In colour, like the filaments with which they were connected, they varied greatly; for, while many were colourless, or exhibited various shades of buff or yellowish, others were of a bright pink or rosy hue. They frequently showed traces of a cellular structure, more or less distinctly. These could, in general, be made out readily by examining the cysts in rather deep focus, so as to bring the profile of their broadest portions into view. The constituent cells of the walls were then clearly brought out, giving rise to an appearance of a looped double outline bounding the mass of the cyst. The cellular structure was also seen to advantage in many cases where rupture of the cyst had occurred, with more or less complete evacuation of the contents. The latter were like their envelopes frequently stained of a pink colour. The precise nature of the connection of the cysts to the filaments, and their mode of development, could not be thoroughly ascertained, as they were so closely entangled among the meshes and covered by the ramifications of the mycelium as to render it a matter of great difficulty to free them for examination, but it was clearly ascertained in several instances that an organic connection existed between them.

The nature of these bodies was for some time a matter of great doubt and obscurity, but they were ultimately ascertained to be imperfectly developed *Eurotia* of the common yellow *Aspergillus* growing on the sides of the bottle and surface of the fluid. Some of them having been observed in many respects very closely to resemble in structure and form the eurotial structures, which we had frequently obtained on the mycelium of *Aspergillus* when submerged or grown on very moist substrata, suggested the renewed examination of the mould on the surface of the water and sides of the bottle —above the fluid in this instance. On doing so, no doubt could remain as to the nature of the submerged bodies. Some of the patches of mould on the sides of the bottle, and which extended from above downwards into the fluid, showed normal yellow specimens of the *Eurotium* of the common yellow *Aspergillus* in their upper portions, and a series of transition forms lower down, until in the submerged parts specimens were present which were precisely similar to the cysts of the deposit, save that none of them were of a pink colour, but all colourless or pale yellow (Plate XXVI, Fig. 6). As however the presence and degree of colouring in the cysts below was not a uniform

phenomenon, and as other organisms present in the cultivation both at the surface and bottom of the fluid showed a pink tint only in those specimens in the latter situation, this difference did not appear to be of any importance. It certainly could not weigh against the numerous points of resemblance or identity in regard to form, size and structure of the cysts, the nature of their contents, and their relations to the filamentous mycelium with which they were connected.

The only question of any importance regarding the submerged specimens related to their development. Were they, and the mycelium bearing them, developed beneath the fluid, or were the submerged flocculi mere fragments of the mould developed above in contact with the air and which had become detached and had subsequently acquired their pink colour beneath the fluid? The latter is perhaps the more probable of the alternatives; but either mode of development may readily have taken place, as there was an abundance of spores produced by the *Aspergillus* heads originally developed, and these may either have germinated above or at the bottom of the fluid. The spore-like bodies produced within the cysts were peculiar, being unlike those in the *Eurotia* of some other forms of *Aspergillus*, and no asci were observed. They may possibly not have been true spores, but merely abortive asci; as, however, similar bodies may be observed in *Eurotia* developed on other substrata, as will be pointed out subsequently, this is a matter of no special importance in so far as the object of the cultivation in the present instance is concerned.

The cultivation was kept under observation for several months, but the only further change of any importance which was observed to occur in it was a gradual increase in the depth and intensity of the colouring of the deposit, which ultimately became in great part of a bright vermilion hue. The colouring matter was tested with liquor potassæ at various stages of its development, but in no case did it show any signs of being affected by the re-agent in a manner similar to that exhibited by the colouring matter of the red concretionary particles of the diseased tissues.

With regard to the development of *Aspergillus* in connection with the products of the disease in the above cultivation, it may be remarked that species of that genus may very frequently be observed in Calcutta on such materials as skin, cartilage, etc., after the rainy season has set in. We have recently had a striking example of this in regard to one of the commonest species of *Aspergillus*. The costal cartilages adherent to the skeleton of a dog were observed to present a mouldy aspect, and this on closer examination was found to be dependent on the presence of an abundance of minute white points. Under a low magnifying power, these were found to consist of perithecia, presenting the normal features, characterising those of *Eurotium*. They were connected with a thin web of white creeping mycelium which formed a network over the surface of the cartilage. The perithecia showed the normal cellular structure and were full of roundish or fusiform spores. The perithecia varied considerably in size, ranging from $\frac{1}{470}''$ to $\frac{1}{280}''$ in diameter, and the spores measured on an average $\frac{1}{4166}''$ by $\frac{1}{3000}''$, or when circular $\frac{1}{4166}''$ (*vide* Plate XXVI, Fig. 8). No asci could be detected.

A portion of the cartilage was removed and set in a moist chamber for further examination. Some of the perithecia assumed a yellowish tint, but the majority remained unchanged, and the principal growth observed occurred in the mycelium. The filaments of this became greatly developed, ramifying and anastomosing over the cartilage and forming closely adherent networks over the surfaces of the perithecia. They presently gave origin to an abundance of erect filaments bearing the ordinary fructification of *Aspergillus*. In many instances these filaments appeared to arise directly from the perithecia, but this was apparently due rather to their origin from adherent mycelial filaments than to the germination of the spores in the interior of the perithecia, or any outgrowth from their walls. The heads of the *Aspergillus* were at first white, and ultimately assumed the bright green tint characteristic of *Aspergillus glaucus*. Spores which had escaped from ruptured perithecia also quickly germinated, and the specimen rapidly became so obscured by a dense growth of mycelium and fructification as to be no longer fit for examination.

Various other macerations of the morbid products of the ochroid variety of the disease were kept under observation during various periods, but in none of them did a development occur as in the case described, nor were any special organisms observed to occur in connection with them which did not equally occur in macerations or other cultivations of other substrata.

C.—Cultivations in which the morbid products of the pale variety had been intentionally inoculated with various spores, etc.

Another series of cultivations was conducted with similar materials, but in which these were intentionally inoculated with the conidia and mycelia of various species of fungi. The following may serve as an example of such experiments and of the results occurring in them.

CULTIVATION VI.—Cultivation of inoculated materials. A mass of roe-like bodies, collected from the cavities in Specimen No. III (page 349) of the present report, were immersed in water for several days, the fluid being occasionally changed in order to remove the spirit. It was then set in a moist chamber, and inoculated with some of the black-capsuled *Mucor* and brown and yellow *Aspergilli*, previously described as occurring abundantly in some of the other cultivations. The fungi rapidly grew and spread over the substratum, covering it with a thick crust principally composed of the fructification of the *Aspergilli*—the brown species occurring in considerable excess of the yellow one.

A month after the inoculation had been performed, this crust was broken up and a layer of bright red matter, varying from rosy pink to strong carmine in colour, was found beneath it on the surface of the substratum. On microscopic examination, this coloured layer was found to be due to a diffused staining of the substratum where the mycelium had penetrated it. Where this had occurred, the material was also

softened, but the penetration of the mycelium, the staining and the softening, were all quite superficial, extending only to a very inconsiderable distance beneath the surface of the mass, which elsewhere retained its ordinary characters entirely unaltered. In many instances the fungal filaments and masses of fallen conidia, although embedded in this coloured basis, did not participate in the staining, but in others the fungal elements were dyed in all shades from pale pink to bright carmine.

In some places filaments and growing heads of both the species of *Aspergillus* were found *in situ*, the stems, rounded heads, sterigmata and spores being stained of the brightest carmine, and one or two similarly dyed specimens of *Mucor* filaments and capsules were likewise encountered (Plate XXVI, Figs. 2—5). In the case of the *Aspergilli* various degrees of staining could be traced among the innumerable heads and conidia present, and a careful determination of the measurements and forms of the latter clearly showed that the rose-coloured specimens were mere varieties of the common yellow and brown species along with which they occurred. The colouring was, as usual, confined to the protoplasmic contents of the cells and filaments, whilst the material forming the cell walls was quite colourless. On testing the colouring matter of the substratum and fungi it was found to resemble that of the red concretions, in being partially bleached and rendered brownish by alkalis and generally restored to its original condition by the subsequent addition of acids. The reaction of the coloured layer was distinctly acid. This red colouring was not of long duration in the cultivation, only remaining visible for about a week after its first appearance. The surface of the substratum then became again covered with a dark-brown coating, principally composed of the spores of the brown *Aspergillus*, mingled with a felt of mycelium belonging to that and the yellow species.

The principal points of interest in this cultivation were—1st, the demonstration afforded of the fact that common moulds, usually occurring on vegetable substances, found the conditions suitable for their abundant growth and fructification, when cultivated on the material of the roe-like masses of the degeneration. 2nd, the development of red colouring matter in the substratum and the coincident staining of the fungal elements. It was specially interesting to obtain coloured specimens of the common conidial fructification of *Aspergillus* in this cultivation in connection with the occurrence of similarly coloured specimens of the Eurotial or sexual fructification of the same genus in the experiment previously detailed.

Numerous other similar experiments with inoculated materials were tried with varying results. In none, however, was any development of red colouring observed to occur. The fungi employed usually grew and fructified freely, ultimately covering the surface of the substratum. All the observations agreed in showing that the fungal elements remained quite superficial, never penetrating deeply into the mass of the material, and that the latter was very persistent and remained to all appearance unaltered during long intervals of time.

(*d*).—*Cultivations in connection with the* RED PARTICLES.

Besides the above-mentioned attempts at cultivation of the black masses, roe-like material and other morbid products of the common varieties of the disease, numerous other experiments of a like nature were also carried on in reference to the red concretions. These, however, do not call for any detailed description, as, although carried out at various times, on various substrata, and under very various conditions, they only agreed in showing the entire absence of any development of peculiar organisms and the extremely inert and resistent nature of the concretions. They were never observed to undergo any perceptible change, save a slight alteration of colour in some instances, even when kept for weeks under observation.

CHAPTER IX.

LESSONS TO BE DERIVED FROM THESE CULTIVATION EXPERIMENTS.

IT will be evident from the above brief account of the results of our attempts at cultivation of the various morbid products of the disease that we have entirely failed in obtaining the development of any special species of fungi or other organisms from the latter. The forms which made their appearance in connection with them were only those which are prone to occur indiscriminately on substrata of most miscellaneous nature, and the only feature characteristic of the specimens developed on these special substrata was the fact that, in some instances, they were stained of a red colour. This, however, is a phenomenon not confined to cultivations on such materials —we have observed its occurrence under very various conditions and in very dissimilar media, among others in solutions of choleraic excreta (Plate XXVI, Fig. 9)—and, even had it been so, the circumstance would have been of no value as an indication of specific peculiarities in the coloured organisms.

Any one who has studied the varied developments of common moulds, or other low vegetable organisms, must be well aware that mere colour, independent of structural peculiarities, is as untrustworthy a basis for the determination of specificity in regard to them as it is in regard to higher organisms. It may, however, be argued that allowing that our experiments showed no evidence of the presence of any peculiar specific forms in the products of the disease, it is sufficient that varieties characterised by certain features, such as colour, were developed. It may be affirmed that the presence of peculiar colours implies a difference of constitution, and a corresponding difference of properties in the coloured varieties, as compared with the ordinary ones, and that the peculiarity of colouring in the varieties with which we are at present concerned coincides with the peculiar property of inducing the "Madura Disease."

We believe, however, that there are points in our observations which negative any such belief, and which justify us in ascribing the peculiarities of colouring to the

nature of the substratum and not to that of any peculiar varieties of organisms present or assumed to be present in it. In one experiment in which the colour was peculiarly well marked, it was not confined to any special vegetable forms, or even to vegetable organisms, but appeared equally in the ciliate infusoria and *Rotifers;* whilst in another cultivation, various species of fungi artificially introduced into the morbid materials became equally highly coloured whilst growing in and on them. It can hardly be supposed that the coloured varieties of *Rotifers* had any connection with the morbid products of the disease, save occurring in the water along with them, and possibly deriving their nourishment from them.

As to the coloured fungi of the other cultivation, it is manifest that their peculiarities were dependent on the conditions under which they were developed or to which they were subjected, for the species affected were not only among the commonest forms of moulds, but only acquired their peculiar characters as to colour when artificially exposed to the influences of the substratum. It would certainly be unwarrantable to assume that varieties arising in such a way under the influence of certain substrata are necessarily endowed with the power of reproducing similar materials elsewhere.

The fact that the colouring matter present in one of the cultivations was identical in its reactions (with acids and alkalis) with the red colouring matter of the concretions, also points to its dependence on the chemical composition of the morbid material, and not to any inherent special property of the fungal elements accidentally or wilfully developed in association with it. Moreover, as was observed in the case of the cultivation of rice-paste forming the second in the series of cultivations here described, and as we have frequently observed in other instances, pink coloration of the elements of various moulds is by no means an uncommon phenomenon in this country, and it is one which is assuredly not confined to cultivations connected with the morbid products of this or any other disease—indeed we have seen it to develop on a dish of drying crystals of lactate of lime, far removed from the place where these cultivation-experiments were being conducted; so that the mere occurrence of it in connection with the affection cannot be regarded as affording any satisfactory evidence in favour of the dependence of the disease on a peculiar species, or even on peculiar varieties of fungi.

It appears to us that the original observations on the occurrence of red coloured fungi, in connection with the products of the disease, point very forcibly in the same direction as the results of the present cultivations, and indicate that, whatever the nature of the organisms observed may have been—whether they belonged to peculiar genera, or species or not—they were quite unconnected with the fungoid elements of these products. It is a remarkable fact that in some instances the coloured moulds were observed, as in our cultivations, in connection with the products of the pale variety of the disease, that is, in connection with materials in which the presence of fungoid elements has never been demonstrated. Moreover they showed no unequivocal evidences of specific identity in the different cases; at all events, in so far

as descriptions and illustrations go, we fail to see that they did so; more than all, they occurred indifferently as developments in cultivations where the materials had been subjected to prolonged preservation in spirit, and in others in which no preservative agent had been employed.

It has been denied that there is any evidence that spores, or other fungal elements, may not retain their vitality and power of germination in spite of prolonged exposure to the influence of alcohol. In spite of the weight justly attached to the opinion of those holding such views, we would inquire whether there be any evidence showing that they are endowed with any such faculty? We are not aware of any; and although by no means wishing to found any sweeping generalisations on limited data, we can only state that the results of our own observations and experiments have been directly opposed to the assumption of the actual existence of such a resisting power.

In connection with the cultivations described in the present report, we have tried numerous careful experiments on the effects of alcohol on the spores and mycelium of fungi, and have never observed such bodies show any signs of having retained their vitality after even very short exposure to the re-agent. In regard to cultivations of the morbid products of the disease Mr. Berkeley's experience is strongly in support of this, for he states that he entirely failed in obtaining any development from the preserved specimens which were submitted to him, and only obtained a growth of pink mould when working, not with the original morbid materials, but with rice-paste on which similarly coloured fungi had previously occurred in Bombay.

Taking everything into consideration, it appears to us that all that has yet been shown by means of cultivations is that fungi and other organisms developed in connection with the morbid products of the "Madura Disease," occasionally present themselves in pink or red coloured varieties; and that this colouring is due to the nature of the material, and not to any specific properties in the organisms. The phenomenon, therefore, is one which cannot be cited as a proof of the fungal origin of the disease or of the presence of fungal elements in materials such as those of the pale variety of the disease, affording no other evidences of their existence.

CHAPTER X.

CONCLUSIONS.

It now only remains for us to summarise the principal points in connection with the peculiar affection of the feet and hands which we have referred to in detail in the preceding pages. It has been seen that the disease appears in two principal forms; that the lesions produced, the particular tissues affected, and the general course of the disease present much in common; but that the morbid products, whether examined chemically or microscopically, are found to be most dissimilar.

In the pale variety this product is for the most part of a fatty nature, abounding in many of the various modifications of fat known to pathologists; whereas in the dark variety, the fatty matter forms a far less prominent feature in some cases; indeed, the dark material may often be referred to as being almost completely devoid of fat—at all events it must have undergone such extensive changes as to be no longer recognisable as such.

It is extremely difficult to account for the discrepancy in the composition of the morbid products of the disease. The inference that the pale is a later stage of the dark variety of the affection, as advocated by Dr. Vandyke Carter, is in our opinion untenable from the fact that, as has been shown on a previous page, the progress of the disease may, in some cases, be traced through all its stages in a single specimen; just as in a tuberculised lung areas may often be distinguished presenting the most recent deposits of tubercle in the midst of tissue far advanced in the degeneration. In Specimen III (page 349), for example, the various steps in the degenerative process could be followed with the greatest ease. Well defined areas could be seen in the midst of, apparently, healthy connective and fatty tissues, and the various stages of the process—trifling consolidation of defined areas of tissue, slight discoloration, nests of roe-like bodies associated or not with crystalline formations, and other changes, could be readily identified, but without any indication of the previous existence of the black substance.

On the other hand we have seen specimens of the dark variety in such a recent stage of the development of the malady, as to negative any idea of its being a later stage of the pale; the dark granules not larger than grains of gunpowder being deposited here and there among the tissues; the only concomitant alterations of the part being slight hardening and trifling discoloration of isolated lobules in the subcutaneous tissue. In one case (Specimen II, page 347) we were able to trace, what appeared to us to be, the progressive stages, in this variety also, of the malady—from the yellowish-brown ceruminous nodule, to the almost perfect black, granular lump.

It is nevertheless quite possible, and indeed probable, judging from the great similarity in the lesions produced, the course pursued by the disease, and its duration in the two forms, that the original cause may be very closely allied if not identical. Pathology has not yet progressed sufficiently to be able to determine why it is that certain degenerations will take very different courses in different persons; nor is the science sufficiently advanced to enable us to refer definitely to the direct cause of almost any single degenerative process. For the most part our etiological conceptions are hypothetical. Consequently we are no further behind in our knowledge of the etiology of this, comparatively, new disease, than we are with reference to causation of the various cancerous and other morbid processes which have been known for centuries.

But do we know *more* as to the cause of this disease than we do of most

others? Certainly the forms under which the disease manifests itself are in many ways different from those ordinarily met with: it is characterised by being localised to certain districts, and by the fact that only certain parts of the body, as far as we at present know, are liable to be affected; and more than all, the morbid product of one, or rather two, of its varieties, the black and the pink, are so particular, as to enable it to be distinguished at once from all other affections. But that these peculiarities should of themselves be sufficient ground for forming any conclusions with reference to the *cause* of the affection, is not supported by the observations which we have made.

The reader of the foregoing chapters will have observed that three of the peculiar morbid products, described as various stages in the development of a peculiar fungus the assumed cause of the disease, have been very carefully investigated, *viz.*, the roe-like bodies; the pink particles, and the black masses.

The first of these we have shown to be fat in various modified forms; the second were found to be pigmented concretions—not the slightest trace of a fungus, or of other vegetable organisms, being present in either; and the third we have shown to consist of degenerated tissue, mixed to a greater or less extent with black pigment and fungoid filaments. To account for the presence of the two latter ingredients is in reality the most difficult problem connected with the affection.

As regards the actual lesions produced in the tissues, it will have been observed that neither of these two latter ingredients are essential, seeing that, with the exception of the physical characters of the morbid products, no marked distinction exists between the pale and the black varieties. Similar tissues are affected in both, the cavities and channels are alike, and the similarity extends even to the peculiar mammillated orifices by which they open on the surface. These circumstances of themselves absolutely negative, in our opinion, the view that anything which may be found in connection with one variety, and not in connection with the other, can be referred to as the specific cause of either. Why these morbid substances should present these anomalies is a totally different question, and one which is not within our province to discuss.

The occurrence of pigmentary deposits in animal tissues is by no means a rare circumstance. Our knowledge as to whence the pigment is derived is not yet very exact, but it is generally believed to be derived from the blood. Its behaviour under the influence of re-agents is however well known, and we have found that the pigment in the dark substance, when treated with re-agents, manifests properties similar to those of ordinary pigment. The presence of iron in the pigmented substance of the Madura-disease, which both Mr. Wood's analysis and our own revealed, is a significant fact, seeing that iron is a constant component of black pigment, a circumstance which, in our opinion, points, almost unequivocally, to the fact that the pigmented substance under consideration originates from the same material as the pigmentary deposits ordinarily met with in animal tissues.

We have already given full particulars regarding the microscopical and chemical properties of the fungal elements associated with the pigment; they resist the action of weak acids and strong alkalis, and manifest all the properties of ordinary fungal forms except vitality; and we believe that it will be generally conceded that it has been shown that on no single occasion has any one been able to coax the fungoid elements in this substance to germinate, much less to develop anything approaching to mature fruit; hence any propositions which may have been advanced with regard to the causation of the Madura-disease on the grounds that a new or peculiar fungus has been developed from the morbid products amongst the tissue are, apparently, without good foundation, and must be carefully considered in the light of the facts now adduced. It is for botanists to decide whether the "*Chionyphe Carteri*" is what is termed a "good species" or not; all we have to do with it is restricted to its purely pathological significance, and, in connection with that, we

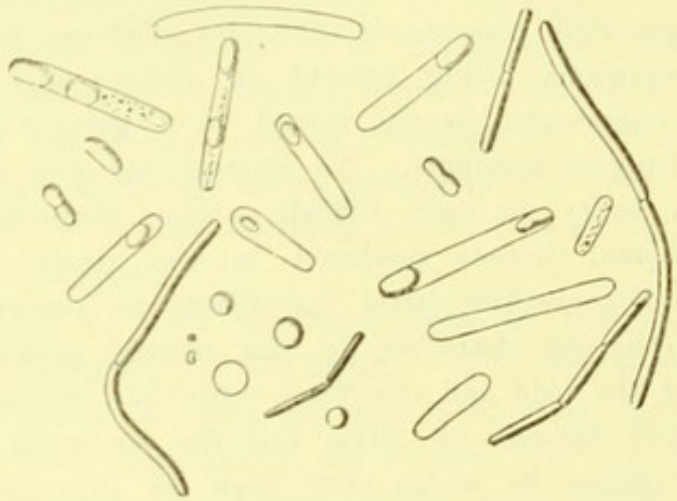

Fig. 15.—Organisms found in the tissues of *healthy* animals a few hours after death × 1,500.

unhesitatingly express our convictions that not only does it not cause the disease, but that it cannot be developed from the fungoid elements contained in the morbid product.

Although we have failed in producing these fungoid elements to grow, it does not follow on that account that they are not, and never have been, vitalised. It is true that a great many purely physical products are found which so closely resemble those which have been moulded under the influence of vitality as not to be distinguishable or only distinguishable with difficulty; such, for example, as the concretions of Mr. Rainey—the *calcospherites* of Professor Harting—the *myeline* of Virchow and the amylaceous corpuscles known to all microscopists; still the optical and physical characters of the filaments and capsules seem to us to agree so perfectly with what we have seen in undoubted fungi that we look upon them as such until the contrary can be demonstrated.

To account for their presence in the tissues—deeply imbedded and far removed

from anything that could suggest the existence of a channel of communication between the spot and the exterior for any such immobile object as a spore—is most puzzling. The supposition that a sporule had managed to insinuate itself by means of some natural, or artificially produced pore, is untenable from the simple fact that perfectly independent *foci* of the affection may be distinguished—so distinctly defined as to necessitate the inference that each localised pigmentary deposit had derived its origin from the introduction (through the cutaneous tissues) into that particular part of a foreign body capable of germinating.

To us it appears much more reasonable to infer that localised spots in the tissues undergo a degenerative change into a substance *peculiarly* adapted to the development of filamentous growths. We ourselves have shown, and it has been shown by others, that under certain conditions—the principal being the absence of vitality or vitality greatly depressed—every tissue in the body is capable of giving rise to the abundant development of complex organisms.

We reproduce a figure (Fig. 15) of some of the leading forms of these growths for convenience of reference from a report which we submitted last year bearing on this matter, as we have since that period undertaken several experiments of a like nature and which have a very direct bearing on the point now under consideration.* The object of the experiments was to ascertain whether by interfering with the

* In connection with this subject the question naturally presents itself as to the degree in which results of this nature are influenced by the conditions of the locality where the experiments are carried out—whether the results which are obtained under the influence of the temperature of a tropical climate are likely to occur in temperate localities with lower temperature. We believe that they are, and this on the ground of the following experiment :—

Body.	Time after death.	Temperature.			
		Liver.	Thigh.	Air.	
No. 1	1 hour	93°5	88°	6 °	Body on a lead-covered table.
	4·5 ,,	91°9	86°5	67°	
	8 ,,	87°0	82°0	68°5	
	15 ,,	84°0	74°0	64°5	
	24 ,,	76°0	69°0	59°	
No. 2	1 hour	95°	95°	62°	Body on a wooden table.
	4·5 ,,	92°	86°	67°	
	8 ,,	87°	81°	68°5	
	15 ,,	84°	74°	64°5	
	24 ,,	76°	69°	59°	

Two men were executed in the Presidency Jail in the month of December 1874. The bodies were removed to the dead-house immediately after having remained suspended for the prescribed period. The following statement shows the temperatures registered at various intervals during the following 24 hours by thermometer nserted into the substance of the liver and the muscles of the thigh in both bodies, compared with the coincident atmospheric temperature.

The loss of temperature is so gradual even when the external temperature is moderate, that in so far as conditions of temperature are concerned, the body, save in exceptional cases, must, for many hours after death, itself provide a suitable temperature for the rapid development of organisms.

vascular supply of certain tissues and organs of the body of an animal without injuring the isolated tissue, we should be able within the course of some hours to detect organisms in those parts in the same manner as we had been able to do when an animal had been killed under chloroform and set aside in a warm place. We found that such was the result, and that a kidney, for example, when carefully ligatured without interfering with its position in the abdomen, would be found after some hours to contain precisely similar organisms; whereas the other kidney—whose circulation had not been interfered with—contained no trace of any vegetation whatever.

Taking everything into consideration, it seems probable to us that some local degeneration takes place in the Madura-disease, giving rise to a product which is, in one of its varieties, peculiarly adapted to the development of vegetable organisms. All microscopists know how frequently the most trifling alteration in the composition of a nutritive medium decides the advent of peculiar growths.

CALCUTTA,
September 1875.

ILLUSTRATIONS.

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XXVII.—The "Dark" variety of the Fungus-Disease, &c. . . . . „ „ 390

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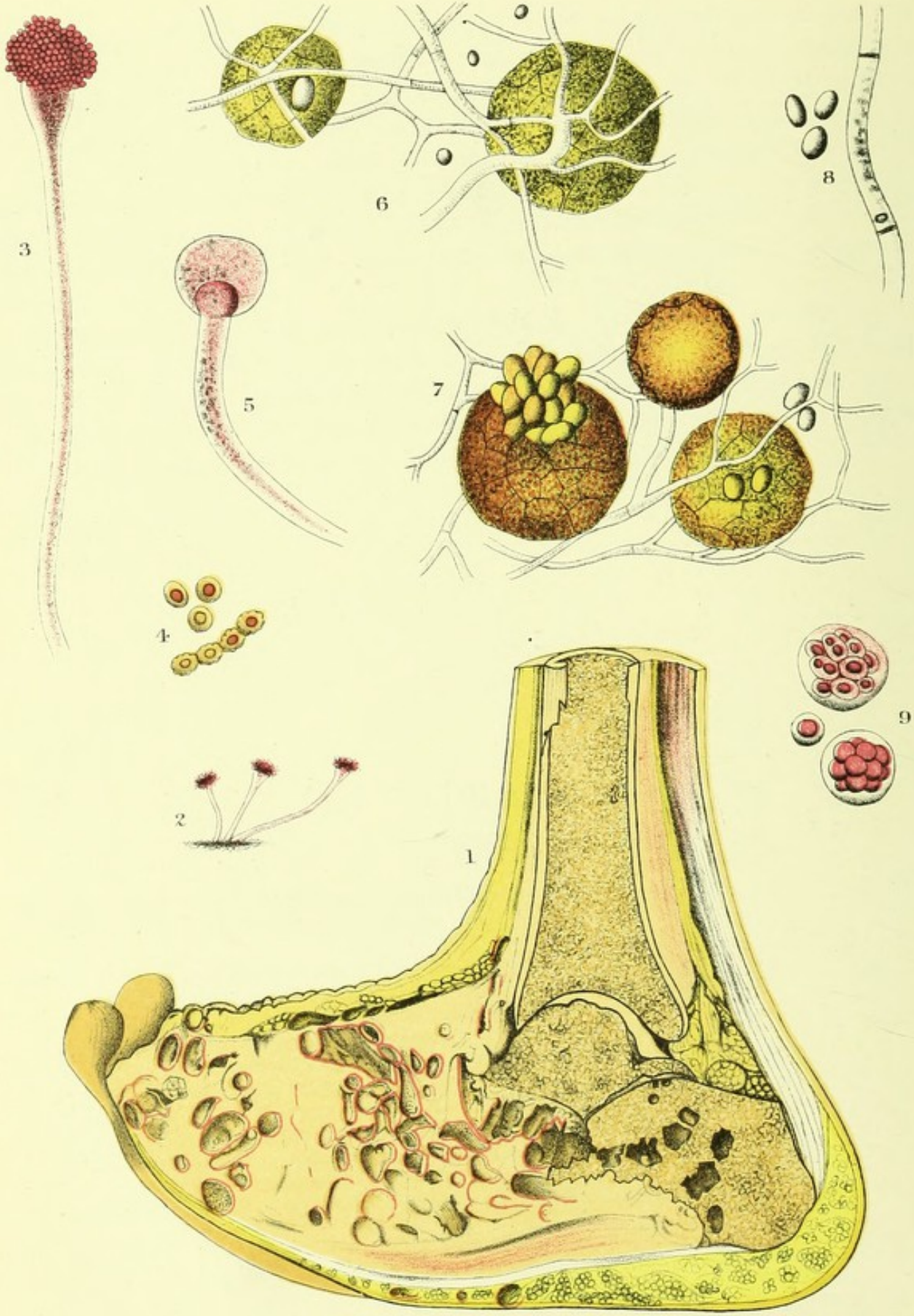


To face p. 389.

THE FUNGUS-DISEASE OF INDIA.

PALE VARIETY, ETC.

EXPLANATION OF PLATE XXVI.

1. Section of a foot affected with the Pale variety of the disease, showing cavities and channels in the substance of the tissues. Isolated masses of subcutaneous fat of the sole of the foot are seen to be affected by the degeneration (*vide* page 348).

2. Rose-coloured variety of *Aspergillus* developed on the roe-like masses of the degeneration (*vide* page 374). × 60.

3. Separate filament of the *Aspergillus* more highly magnified, showing the staining of the plasma × 250.

4. Spores of *Aspergillus* from the same cultivation, showing normal and rose-coloured varieties. × 950.

5. Young head of *Mucor* from the same cultivation, showing red-colouring of the contents. × 950.

6. *Eurotium* developed on the surface of a fluid in which portions of the degenerate material, from a foot affected with the Pale variety of the disease, were immersed (*vide* page 373). × 400.

7. Rose-coloured variety of the same *Eurotium* occurring beneath the fluid in the same cultivation. × 400.

8. Specimens of spores and a portion of a filament from *Eurotium* developed on cartilage in Calcutta. × 600.

9. Rose-coloured cells (*Algæ?*) developed in a cultivation of choleraic excreta in water. × 300.

EXPLANATION OF PLATE XXVII.

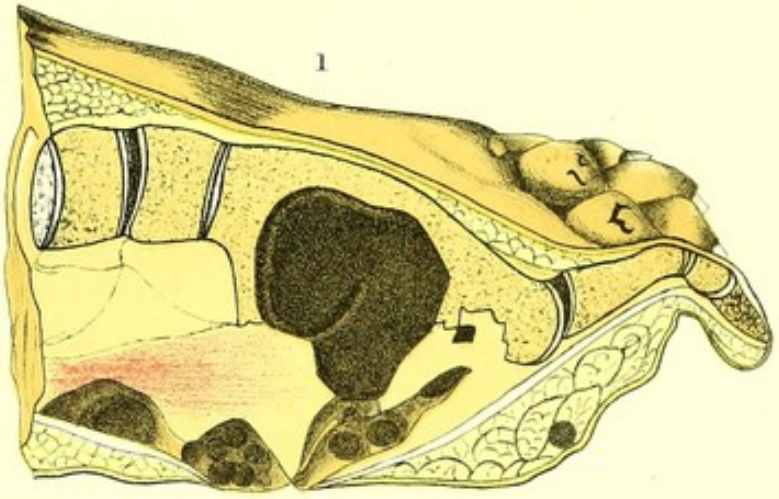
1. Section of a specimen of the dark variety of the disease, showing a large mass in the substance of the second metatarsal bone, with cavities and channels containing black masses in the soft tissues. An isolated lobule of subcutaneous fat affected by the degeneration is present beneath the base of the first phalanx of the toe (*vide* page 362).

2. Section of another specimen, in which the disease was principally developed round the ankle, showing the freedom of the tendons from degeneration, although surrounded by diseased tissue. In the subcutaneous fat of the dorsum of the foot several isolated spots of degeneration have been exposed by the section (*vide* page 359).

3. Red particles from a specimen of the disease (*vide* page 351), — 40.

4. Similar bodies more highly magnified, — 92.

5. 6. Specimens showing transitions of the subcutaneous fat into the caseous matter forming the concretion in the pale variety of the disease (*vide* page 350)—slightly magnified.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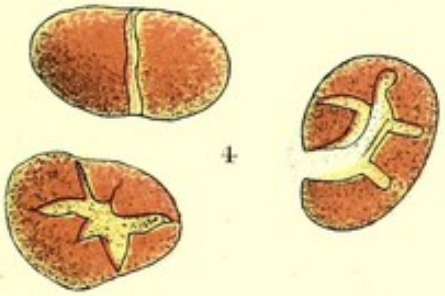
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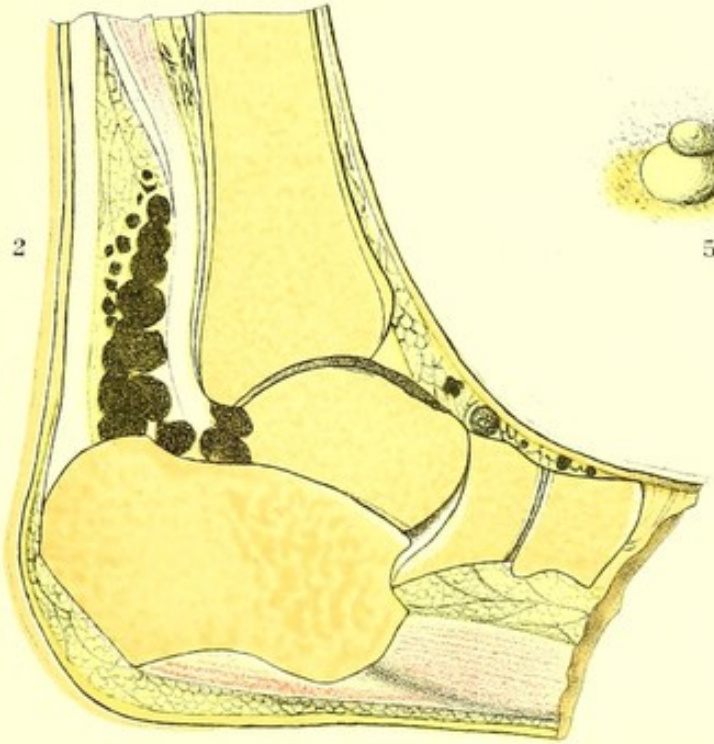
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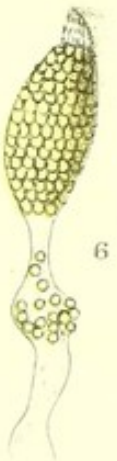
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THE "ORIENTAL SORE"
AS OBSERVED IN INDIA.*

A REPORT

BY

T. R. LEWIS, M.B., AND D. D. CUNNINGHAM, M.B.

CHAPTER I.

GENERAL REMARKS REGARDING "ORIENTAL SORE:" ITS DELHI FORM.

THE subject of which the present report treats has occupied our attention for several years past, but it was only during the earlier part of the present year that we were able to devote time specially to its study in the locality where it has generally been considered to prevail to a greater extent than any other in India, namely, at Delhi. The complaint has been known in that city for many years, but it was not until after 1857 that special attention was drawn to it by the large amount of invaliding which it produced amongst the European troops who were stationed there after the mutiny. Since this period the disease has occupied a prominent place in the literature of cutaneous affections under the designations of "Delhi sore," "Delhi boil," or "Delhi ulcer." The Government appointed a Commission, presided over by Dr. John Murray, to report upon the subject in 1864, and subsequent to this numerous medical officers have made special investigations regarding the origin and nature of the sore, foremost among whom may be mentioned Dr. Alexander Smith and Dr. Joseph Fleming.

As, however, the literature of the complaint has been very recently lucidly summarised in a joint work by Drs. Tilbury Fox and Farquhar on the "Skin Diseases of India," published under the sanction of the India Office, we do not consider it necessary to particularise the various views which have been propounded from time to time regarding the malady, and shall restrict ourselves to giving a

* Appeared as an Appendix to the *Twelfth Annual Report of the Sanitary Commissioner with the Government of India*, 1876.

précis of the observations which were conducted by ourselves in accordance with the instructions which we received from the Government of India. We may, however, mention that a short but very accurate description of the sore has recently been published by Sir Joseph Fayrer,* but which seems to have appeared too late to be referred to by the authors of the above work. Though occupying a few pages only, it expresses pretty nearly all of value that has been written regarding the matter.

One of the chief results of the many contributions to the literature of the subject has been the identification of this sore with sores occurring in other districts and cities of India—cities and districts which have likewise given it a local signification by lending it special names. The consequence has been that Scinde, Mooltan, Roorkee, Meerut, Lahore, Lucknow, and other places have all been credited with the prevalence of a peculiar sore or boil. These, again, have all been pretty conclusively identified with similar affections very prevalent in parts of Syria, Egypt, Arabia and other Oriental countries, where they have received such designations as the "*Boutons*" of Aleppo, Biskra, Bagdad, Bussorah, and so forth.

Additional importance has been attached to the prevalence of the disease at Delhi from the circumstance of its being associated with the name of the celebrated Emperor Aurangzeb, who, it is popularly believed, suffered from the affection. Some even go so far as to say that it was the immediate cause of his death. In Delhi itself the affection is commonly described as "Aurangzeb" without any further qualification.

Having failed to trace any definite reason for this general belief in the works of Tavernier, who wrote minutely regarding Aurangzeb's times, or in the works of Bernier (the latter writer was for many years physician at the Court of Aurangzeb at Delhi, and nevertheless makes no mention of the Emperor having suffered from any such complaint), we consulted Professor Blochmann, the well known Oriental scholar, and he very kindly favoured us with the accompanying note,† from which it will be seen that, even according to all the original independent historians of this Emperor's reign, there exists no foundation for the general belief that the Emperor suffered from any special cutaneous affection.

In another communication to us Mr. Blochmann makes a suggestion as to

* "The Practitioner," October 1875, pages 264—267.

† "Muhammadan historians do not state that the Emperor Aurangzeb (or Álamgír, as natives call him) died of Delhi sores. For his reign we have only three *independent* historical works, *viz.*, the Maásir-i-Álamgírí, Kháfi Khán, and the Tabsirat-un Názirín; and of these Kháfi Khán only gives a more detailed account of the Emperor's illness and death. He says (Edit. Bibl. Indica, II, page 539):—

"'At this time (a short time before Ramazán 1117, or January 1705) His Majesty fell seriously ill. He felt an extraordinary and most acute pain in all joints, which extended to every limb. Although he tried to keep down the sickness and continued to decide Government matters, in order not to dishearten the people, his illness continued, and when one or two fainting fits supervened, a great commotion took place among the soldiers and the camp-followers. At last, however (the Maásir-i-Alamgírí says, after ten or twelve days), His Majesty's health again improved. . . . On the recommendation of Hakím Sádik Khán, His Majesty took doses of *chobchini* (China root), and continued doing so for three or four weeks. Every day during the treatment, sums of money were given to the poor; and, when the cure was effected, the

whether the term may not have originated on account of some supposed resemblance of the sore to a kind of cloth termed "Aurangzeb." Be this as it may, there can be no doubt that the association of the disease with the Emperor is based on no authentic ground. Moreover, the Emperor lived far from Delhi for several years before his death. It may further be noted in connection with this matter that the Moghuls, no matter where they lived, used nothing but Ganges water for drinking and cooking purposes.

With the view of bringing all these designations under one heading, we have in the present report adopted the term "Oriental Sore," which has been suggested by Dr. Tilbury Fox, but restrict our observations, as far as the pathology of the disease is concerned, to the examples of it met with in this country, especially to those found in Delhi, which are acknowledged to represent the type of the malady as it occurs in India.

CHAPTER II.

STATISTICS ILLUSTRATIVE OF THE GEOGRAPHICAL DISTRIBUTION AND PREVALENCE OF DELHI SORES AND ALLIED AFFECTIONS.

In considering the question of the etiology of the Delhi sore, it is necessary not only to obtain information in regard to the prevalence of the disease in this special locality, but to ascertain, as far as possible, to what extent similar or related forms of disease prevail, and have prevailed formerly, in other parts of the country Unfortunately all the information attainable is, at best, very imperfect. In the statistical tables relative to the health of the European and native armies, sores, such as those occurring in Delhi, are entered along with a variety of other affections under the general heading of "abscess and ulcer," and in many tables under the more comprehensive one of "all other causes," along with a heterogeneous mass of minor forms of ailments causing admissions into hospital.

In turning to other sources, such as the medical histories of regiments, we are again encountered by various sources of fallacy, the most important being due to the

Hakim was weighed against gold mohurs, which were given him. He also got the title of *Hakim-ul-Mulk* ("physician of the empire"). By the end of Rajab (November 1705) His Majesty moved to Bergáon.'

"But during 1118 (1706 A.D.) Aurangzeb continued ill, and his life was embittered by the hostilities that had broken out between his son A'zam Shah and Kám Bakhsh. When the two princes, after the month of Ramazán (January 1707), left the Emperor's camp for their provinces, 'the pain His Majesty suffered increased, the fever was very strong, and yet His Majesty, in spite of his illness, performed the five daily prayers.' The *Maásir* (Edit. Bibl. Indica, page 520) says: 'In the end of Shawwál 1118 (January 1707) the Emperor was again ill, and improved a little. Then followed four or five days of strong fever, and three days later he died on Friday morning, 28th Zi Ka'dah 1118' (21st February, 1707).*

"There are several other historical works, as the Tazkirah-i-Salátín-i-Chaghtái, the Siyar-ul-Mutaakh-kharín, the Tárikh-i-Muzaffari, etc., but they contain nothing new."

* Nearly ninety years old.

local name commonly applied to the disease. Observers are not prepared to recognise Delhi, Mooltan, Scinde, etc., sores out of the places giving the local names, so that unless in cases where the reporter has been in such stations, no indication is afforded of the existence of such forms of disease beyond that to be gleaned from the general prevalence of ulcers, and their more or less chronic nature when this is noted.

Taking the material as it stands, the following pages show the amount of information which it appears capable of affording.

1.—*Prevalence of "Abscess and Ulcer" as a cause of "Admission into Hospital" in different places and at different times.*

The following table shows the general admission rates of the European and native armies of Bengal, from 1861 to 1874, contrasted with those from "abscess and ulcer." The year 1861 is the date selected as a commencement, because it is the first year from which we have information regarding the native troops; but it may be mentioned here that the average total admission rate from all causes, and that from abscess and ulcer, among the Europeans for the five previous years, regarding which we have any information (1854, 1855, 1856, 1859-60), were respectively 2307·0 and 128·9 per thousand.

TABLE I.

Total Admission Rates, and Admission Rates from "Abscess and Ulcer," of the European and Native Armies of Bengal.

Year.	Europeans.		Natives.	
	Total admissions per 1,000.	Abscess and Ulcer per 1,000.	Total admissions per 1,000.	Abscess and Ulcer per 1,000.
1861	2045·6	114·6	1169·0	109·5
1862	1970·8	106·7	1384·5	134·6
1863	1838·4	99·7	1476·5	124·7
1864	1641·6	130·4	1388·7	149·4
1865	1605·3	119·0	1475·6	131·1
1866	1501·7	101·3	1385·8	147·8
1867	1412·5	86·4	1447·7	121·5
1868	1438·3	105·9	1175·8	105·4
1869	1729·5	94·6	1501·1	95·7
1870	1731·9	85·0	1492·3	101·7
1871	1507·7	86·3	1287·2	106·2
1872	1514·1	80·2	1496·0	93·4
1873	1349·8	80·9	1289·5	88·5
1874	1443·8	84·7	1266·5	93·7

From this table we see that there has been a very considerable diminution in the admissions from abscess and ulcer among the Europeans coincident with a great

general diminution of admissions from all causes. Among the native troops the diminution under the special heading is very marked, but the general admission rate shows little, if any, sign of steady diminution. The only other diseases which have shown a considerable diminution among native troops for the same period are diarrhœa and dysentery, and they do not do so nearly so decidedly as abscess and ulcer. Having thus seen that there has been a general diminution in abscess and ulcer coincident with improved general health of the troops dependent, beyond doubt, on attention to sanitary improvement, we may next proceed to matters of more detail.

The next table shows the relative prevalence of abscess and ulcer among the troops in different parts of the country from 1865 to 1874.

TABLE II.

Admission Rate per 1,000 *from Abscess and Ulcer in different parts of the country.*

Year.	European Troops.							Native Troops.						Irregular Forces.	
	Bengal Proper.	Gangetic Provinces.	Rohilkund and Meerut.	Agra and Central India.	Punjab.	Hill Stations.	Bengal Presidency.	Bengal Proper and Assam.	Gangetic Provinces.	Rohilkund and Meerut.	Agra and Central India.	Punjab.	Bengal Presidency.	Punjab Irregular Force.	Central India Irregular Force.
1865	123·8	105·0	142·3	129·0	115·4	...	119·0	103·8	124·5	157·1	169·6	128·0	131·1	153·3	124·3
1866	89·1	99·5	112·6	101·1	99·9	...	101·3	157·1	127·6	174·4	173·7	133·0	147·8	139·0	116·3
1867	118·8	93·9	90·0	98·0	71·0	...	86·4	114·5	124·7	107·8	160·7	110·1	121·5	134·3	82·4
1868	135·5	114·3	98·0	107·6	97·2	...	105·9	91·8	127·8	86·1	122·6	98·6	105·4	124·4	90·7
1869	89·3	100·2	99·1	86·9	94·0	...	94·6	71·7	114·3	78·1	182·0	81·4	95·7	115·2	110·5
1870	80·7	81·5	87·6	90·8	84·4	46·5	85·0	85·1	110·2	77·3	147·6	103·6	101·7	144·1	77·2
1871	87·1	95·0	113·8	94·7	75·5	68·7	86·3	93·4	106·3	68·1	138·2	118·8	106·2	172·5	76·5
1872	78·0	99·3	93·2	63·6	77·3	50·0	80·2	82·0	93·2	75·6	154·8	91·7	93·4	146·5	94·5
1873	75·3	110·1	81·6	70·9	77·3	50·6	80·9	88·1	89·0	79·5	117·2	85·5	88·5	142·5	94·8
1874	92·2	107·3	84·9	82·0	79·8	62·5	84·7	87·5	92·3	83·5	117·7	93·0	93·7	128·4	82·7
Average for ten years	96·9	100·6	100·3	92·4	87·1	55·6	92·4	97·5	110·9	108·7	148·4	104·3	108·5	140·0	94·9
Average for first five years	111·3	102·5	108·4	104·5	95·5	...	101·4	107·7	123·7	140·7	161·7	110·2	120·3	133·2	104·8
Average for second five years	82·6	98·6	92·2	80·4	78·8	55·6	83·4	87·2	98·2	76·8	135·1	98·5	96·5	146·8	85·1

The general diminution demonstrated by the previous table is here (Table II) shown to have been due to improvement in each individual area for both European and native troops. The native troops of the Punjab frontier, in place of any diminution, show a considerable increase; but as the former table only shows the figures for the regular army, this peculiarity may be set aside for the present. Taking the figures regarding Europeans alone first, we find that the Gangenic Provinces give the highest average rate, followed successively by Rohilkund and Meerut, Bengal, Agra and Central India, the Punjab, and the hill stations. Taking the average for the ten years, Rohilkund and Meerut is almost equal to the Gangetic Provinces; but this is almost entirely due to the two first years, as the averages for the two periods of five years included in it very distinctly show.

TABLE III.

Admission rate from All Causes at Stations in which a rate of 70 *per* 1,000 *and upwards of admissions from "Abscess and Ulcer" have occurred in European Infantry Regiments.**

STATION.	ADMISSION RATE FROM ALL CAUSES PER 1,000 AVERAGE STRENGTH.										Average.	Number of times in which stations have given high Ulcer-rates during 10 years.
	1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.		
Berhampore	—	—	—	**2283·8**	—	—	—	—	—	—	—	
Darjiling	941·0	**1173·1**	644·8	943·9	1000·0	1890·6	1121·2	929·4	561·0	1084·3	1028·9	Once.
Ranikhet	—	—	—	—	—	—	**1816·0**	1194·2	982·4	838·1	1207·6	
Solon	—	—	—	—	—	—	—	—	—	**1082·2**	1082·2	
Dugshaie	1023·6	610·4	756·5	568·4	612·0	641·7	**1256·3**	694·7	**1299·2**	711·0	817·3	Twice.
Rai Bareilly	**1098·4**	**980·0**	684·5	—	870·1	—	—	—	—	—	908·2	
Jubbulpore	2184·6	**2698·9**	**2015·8**	1308·0	2136·2	**2547·0**	1380·4	579·2	687·1	922·7	1645·9	
Jullundur	**935·6**	1636·1	652·3	**1574·6**	2632·4	**2269·1**	1142·5	1002·5	926·8	1089·4	1386·1	
Mooltan	1259·5	943·2	836·2	**1271·3**	**2059·1**	**1846·8**	1019·0	1517·4	1531·8	1147·3	1343·1	Three times.
Moradabad	**862·1**	**1239·4**	**1204·0**	715·7	935·9	812·3	1066·3	848·8	738·4	980·0	890·2	
Subathoo	**1409·3**	**1249·2**	1163·8	731·3	1200·0	690·7	920·9	**727·8**	839·4	628·8	956·1	
Bareilly	**1037·5**	**853·0**	**1012·4**	**836·5**	1208·2	780·6	794·5	1166·2	871·1	1035·5	965·2	
Delhi	**1580·0**	1230·0	1950·0	1986·0	**2262·8**	1543·7	**2162·8**	**2578·6**	1279·4	1934·6	1850·7	
Nowshera	1910·0	**2282·3**	**1452·1**	1522·6	2167·6	2762·9	3395·5	**2434·3**	2028·4	**1870·5**	2182·6	Four times.
Rawul Pindi	**1325·5**	1420·5	**1212·3**	1256·4	2472·2	2138·2	1801·8	**1157·6**	**1185·4**	1100·3	1507·0	
Seetapore	**1413·3**	961·1	747·4	978·3	1285·7	1178·6	809·1	**901·3**	**1031·7**	**1496·0**	1080·2	
Agra	1833·4	**1599·8**	**130 ·2**	**993·4**	973·4	1751·6	**1380·1**	1222·3	824·4	**1434·3**	1332·0	
Ferozepore	**1507·6**	**1521·1**	**1421·8**	**1419·8**	1727·8	**1573·8**	1082·6	1166·0	1030·6	1173·1	1362·1	Five times.
Cawnpore	1443·2	1136·5	1356·1	1292·2	**1341·3**	**1764·6**	**2178·0**	**2414·2**	**1537·4**	**1443·0**	1590·6	
Dum-Dum†	**2351·4**	**2466·2**	**1118·6**	1724·3	1310·0	**1019·7**	1050·6	1403·1	**628·7**	**780·3**	1385·2	
Fyzabad	**1537·3**	**1186·8**	809·5	**819·1**	887·5	**1304·9**	880·7	989·7	**1829·1**	**1242·4**	1148·7	
Mean Meer	1273·7	1691·8	2290·3	**2109·4**	**3392·2**	**2687·3**	**1455·3**	**2498·5**	2934·3	**2273·1**	2260·5	Six times.
Morar	**1713·9**	**1853·3**	**2086·4**	**1697·7**	2485·5	**1860·6**	2460·0	**1489·8**	968·1	1219·9	1773·5	
Peshawur	**2837·4**	**1666·3**	2021·8	2028·1	2998·2	**4061·3**	**2242·6**	**2877·7**	2205·0	**2989·7**	2592·8	
Allahabad	**1220·1**	1620·6	**1628·4**	**1848·4**	**2580·2**	1578·4	1673·8	**1660·0**	**1805·4**	**1594·1**	1725·4	
Dinapore	**1574·4**	**1927·1**	**1350·6**	**1580·8**	1429·1	1197·9	**1442·2**	1875·7	**1196·4**	**1982·8**	1525·9	
Hazaribagh	**1420·7**	**1813·9**	**979·4**	1807·7	1086·9	877·7	**1384·4**	**1118·3**	**896·2**	**1088·9**	1247·4	
Roorkee	860·0	**770·0**	2350·0	**941·7**	**1849·6**	1571·4	**1651·6**	**1679·9**	**936·4**	**1075·9**	1368·6	Seven times.
Sagar	**2608·5**	**2715·8**	**2118·7**	**1682·8**	**2265·7**	**2031·7**	**1718·1**	1559·2	1427·1	1929·5	2005·7	
Shajehanpore	**1820·4**	**1410·6**	**1440·7**	723·1	639·6	883·5	**2178·6**	900·0	777·3	—	1197·0	
Sialkote	**1135·0**	**1253·6**	**1303·5**	**1238·2**	6541·6	**1668·0**	1154·2	1471·9	**1319·6**	**1109·8**	1319·5	
Umballa	**1678·4**	**1208·3**	**1231·0**	**1497·9**	1355·9	**1482·9**	1234·5	1319·6	**1468·3**	**1628·4**	1410·5	
Fort William	**1712·3**	1660·5	**1760·5**	**1355·5**	**983·4**	**1289·1**	**1230·0**	**1980·7**	**1353·9**	840·7	1416·6	
Jhansi	**1965·5**	1832·7	2225·3	**1989·2**	**3257·0**	**2946·3**	**3042·3**	**2688·3**	**2183·5**	**2154·2**	2428·4	Eight times.
Meerut	**1886·7**	**1377·9**	**1511·1**	**1270·4**	**1411·0**	**1593·7**	**199 ·1**	**1972·9**	1575·4	2739·6	1733·3	
Benares	**2360·7**	**1660·5**	**1788·2**	**1402·7**	**1484·2**	**1377·9**	1262·6	**1466·5**	**1088·6**	**1577·4**	1546·9	Nine times.
Lucknow	**1184·7**	**1230·3**	**1143·2**	**1223·4**	**1204·0**	**1410·8**	**1094·4**	**1496·3**	**1296·7**	1208·4	1258·2	
Total Stations giving 70 per 1,000 of admissions from Abscess and Ulcer.	25	23	20	20	13	19	15	17	16	17	—	
Average admission rate from All Causes	1555·8	1496·4	1399·2	1343·5	1795·5	1668·0	1531·7	1499·6	1271·8	1398·3	—	

* The years which gave a high rate of Admissions from "Abscess and Ulcer" at the several stations are distinguished by the figures of the Admission-rate from "All Causes" being printed in larger type.

† The Regiments at Dum-Dum, as a rule, supplied detachments to Berhampore until June 1870; consequently the returns of the two stations are usually included in this statement up to that date.

The table on page 396 shows the individual stations in which Infantry regiments have given over 70 per cent. admissions from abscess and ulcer, together with the years in which they have done so from 1865 to 1874, and the general admission rate of the station for each year. In this table the years with high ulcer rates are distinguished by the difference in the type with which the general admission rate is printed. Only Infantry regiments have been taken into account, Cavalry regiments and Batteries having been set aside on account of the small numbers of men contained in them, and as regards the Artillery, moreover, because there are no native troops of a corresponding nature.

The table also shows the average admission rate, from all causes, of each station for the ten years, and the average admission rate of all stations for each year. The stations are arranged in groups according to the number of years in which the admission rates of regiments in them from abscess and ulcer attained or exceeded 70 per 1,000. This number varies from one year in the case of certain hill stations to nine in Benares and Lucknow. It will be seen that during the period under review there has been a considerable diminution in the number of stations, giving 70 and upwards per 1,000 admissions in any individual year. It also appears that there is no necessary correspondence between the average total admission rate of any station and the prevalence of abscess and ulcer in it. Lucknow, for example, with a very low average total admission rate, is one of two stations giving excessive admissions from abscess and ulcer in nine of the ten years. It is, moreover, not necessarily the case that in any individual station the years of highest general admission rate should coincide with those giving the highest admission rates from abscess and ulcer and *vice versâ*.

The next table shows the same stations arranged as before in order of frequency of high prevalence of abscess and ulcer, but in addition contains the actual rates and the individual regiments giving these in each year.

TABLE IV.

Stations at which the Admission Rates from Abscess and Ulcer in European Infantry Regiments have been 70 *per* 1,000 *and upwards, with the Years, Regiments and Actual Rates.*

Station.	Regiment.	Admission Rate from Abscess and Ulcer per 1,000.									
		1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.
Berhampore *	2-25th Wing	...	...	...	110	...	...	...	...	...	...
Darjiling ...	58th Head-Quarters	...	106	...	...	...	...	...	..	...	...
Ranikhet ...	2-1st Wing	...	...	...	...	...	...	140	...	...	...
Solon	36th Wing	...	...	...	...	...	...	...	...	...	77
Dugshaie ...	85th	...	...	...	...	...	...	78	...	...	...
	37th	...	...	...	...	...	...	...	...	102	...
Rai Bareilly	2-12th Wing	116	107	...	...	...	...	...	...	...	...
Jubbulpore ...	1-23rd	...	75	113	...	...	...	...	...	...	...
	2-12th	...	...	...	...	...	70	...	...	...	...

* Separate admission rate only given for 1868.

TABLE IV.—(*Continued.*)

Stations at which the Admission Rates from Abscess and Ulcer in European Infantry Regiments have been 70 *per* 1,000 *and upwards, with the Years, Regiments and Actual Rates.*

Station.	Regiment.	Admission Rate from Abscess and Ulcer per 1,000.									
		1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.
Jullundur ...	1-19th	73	...	...	...	...	...	...	...	...	...
	92nd	...	...	...	113	...	95	...	...	...	...
Mooltan ...	109th	...	...	...	141	208	106	...	...	...	...
Moradabad ...	36th	86	105	98	...	...	...	...	...	...	...
Subathoo ...	38th	308	142	...	...	...	...	...	...	...	...
	2-12th	...	...	...	...	...	...	...	73	...	...
Bareilly ...	77th	83	88	...	...	...	...	...	...	...	...
	37th	...	...	106	88	...	...	...	...	...	...
Delhi	98th Wing	93	...	...	...	...	...	...	...	...	...
	79th ,, ...	...	...	...	...	89	...	...	...	...	...
	109th ,, ...	...	...	...	...	...	...	208	102	...	...
Nowshera ...	90th	...	81	...	...	...	...	...	...	...	...
	1-19th	...	...	80	...	...	...	...	...	...	...
	2-60th	...	...	...	...	...	...	...	76	...	...
	39th	...	...	...	...	...	...	...	...	...	79
Rawul Pindi...	42nd	77	...	...	...	...	...	...	...	...	...
	3rd Battalion Rifle Brigade ...	...	...	74	...	...	...	...	...	...	...
	70th	...	...	...	...	...	...	...	95	71	...
Seetapore ...	2-12th Head-Quarters... ...	95	...	...	...	...	...	...	...	...	...
	1-3rd ,, ...	...	...	...	...	...	...	...	79	97	...
	1-14th ,, ...	...	...	...	...	...	...	...	...	...	90
Agra	41st	...	104	82	80	...	...	...	...	...	...
	65th	...	...	...	...	...	...	111	...	...	...
	59th	...	...	...	...	...	...	...	...	...	77
Ferozepore ...	1-7th	109	...	...	...	...	...	...	...	...	...
	97th	...	226	...	...	...	...	...	...	...	...
	1-5th	...	...	118	86	...	...	...	...	...	...
	39th	...	...	...	...	...	77	...	...	...	...
Cawnpore ...	1-14th	...	...	...	...	130	95	98	...	...	...
	1-8th	...	...	...	...	...	...	...	83	104	...
	73rd	...	...	...	...	...	...	...	...	...	115
Dum-Dum* ...	55th	99	...	...	...	...	...	...	...	...	...
	91st	...	82	...	...	...	...	...	...	...	...
	27th	...	...	72	...	...	...	...	...	...	...
	96th	...	...	...	...	...	73	...	...	...	...
	62nd	...	...	...	...	...	...	...	...	74	72
Fyzabad ...	1-11th	126	89	...	70	...	...	...	...	...	...
	26th	...	...	...	...	...	72	...	...	...	...
	51st	...	...	...	...	...	...	...	...	88	104
Mean Meer ...	85th	...	...	...	122	108	118	...	...	...	...
	37th	...	...	...	...	...	...	77	118	...	...
	36th Head-Quarters	...	...	...	...	...	...	...	...	...	109
Morar ...	34th	701	113	...	...	...	...	...	...	...	...
	103rd	...	...	89	89	...	...	...	...	...	...
	1-11th	...	...	...	...	...	76	...	76	...	...
Peshawur ...	51st	78	...	...	...	...	...	...	...	...	...
	90th	117	...	...	...	...	...	...	...	...	...
	1-19th	...	118	...	...	...	...	...	...	...	...
	38th	...	...	...	...	...	70	...	...	...	...
	1-6th	...	...	...	...	...	...	103	71	...	...
	2-60th	...	...	...	...	...	...	85	...	...	...
	1-17th	...	...	...	...	...	...	...	...	...	85
	72nd	...	...	...	...	...	...	...	...	...	90

* Supplied detachments to Berhampore until June 1870.

TABLE IV.—(*Continued.*)

Stations at which the Admission Rates from Abscess and Ulcer in European Infantry Regiments have been 70 *per* 1,000 *and upwards, with the Years, Regiments and Actual Rates.*

Station.	Regiment.	Admission Rate from Abscess and Ulcer per 1,000.									
		1865.	1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.
Allahabad ...	107th	84	...	100	119	...	...	...	...	...	...
	58th	...	...	...	...	74	...	...	...	...	...
	2-19th	...	...	...	...	...	...	...	112	149	122
Dinapore ...	1-20th	80	...	...	...	...	...	...	...	...	...
	105th	...	183	207	105	...	...	...	...	...	...
	96th	...	...	...	...	...	...	87	...	73	...
	109th	...	...	...	...	...	...	...	...	...	94
Hazaribagh ...	27th	96	77	...	...	...	...	...	...	...	...
	91st	...	...	79	...	...	...	...	...	...	...
	63rd	...	...	...	...	...	...	71	115	123	...
	2-22nd	...	...	...	...	...	...	...	...	...	118
Roorkee ...	98th Head-Quarters	...	92	...	...	...	...	...	...	...	...
	79th „	...	...	...	87	77	...	...	...	...	...
	109th „	...	...	...	...	...	...	129	104	83	...
	55th „	...	...	...	...	...	...	...	...	...	85
Sagar	97th	162	...	...	...	...	...	...	...	...	...
	1-7th	...	98	106	109	76	...	...	...	...	...
	1-19th	...	...	...	...	...	105	75	...	...	...
Shajehanpore	36th Head-Quarters	188	99	95	...	...	...	...	...	...	...
	2-25th „	...	...	...	80	...	...	...	...	...	...
	37th „	...	...	...	...	71	131	...	...	...	...
	2-1st „	...	...	...	...	...	...	121	...	...	...
Sialkote ...	93rd	168	115	...	...	...	...	...	...	...	...
	38th	...	...	85	105	...	...	...	...	...	...
	58th	...	...	...	...	...	103	...	...	...	...
	1-6th	...	...	...	...	...	...	...	...	75	80
Umballa ...	94th	126	82	79	...	...	...	...	...	...	...
	106th	...	...	...	101	...	110	...	...	...	...
	72nd	...	...	...	...	...	...	...	...	80	...
	4th Battalion Rifle Brigade ...	...	...	...	...	...	...	...	...	...	100
Fort William	54th	85	...	...	...	...	...	...	...	...	...
	2nd Battalion Rifle Brigade ...	...	...	85	...	...	...	...	...	...	...
	2-60th	...	...	...	102	...	...	...	...	...	...
	26th	...	...	...	...	90	...	...	...	...	...
	2-19th	...	...	...	...	...	86	97	...	...	...
	1-14th	...	...	...	...	...	...	...	70	70	...
Jhansi ...	104th	97	...	...	...	...	...	...	...	...	...
	93rd	...	...	...	88	84	...	...	...	...	...
	2-1st	...	...	...	...	...	71	...	...	...	...
	106th	...	...	...	...	...	...	73	80	105	...
	63rd	...	...	...	...	...	...	...	...	...	111
Meerut ...	2nd Battalion Rifle Brigade ...	131	96	...	...	...	...	...	...	...	...
	1-3rd	...	...	85	99	...	...	...	...	...	...
	105th	...	...	...	...	79	77	70	87	...	...
Benares ...	58th *	147	88	266	115	...	...	...	...	...	...
	2-60th Wing	...	...	...	...	130	120	...	...	...	...
	1-3rd	...	...	...	...	..	...	...	108	125	...
	1-14th	...	...	...	...	...	...	...	...	...	110
Lucknow ...	46th	91	125	95	...	...	...	...	...	...	...
	55th	...	78	80	77	...	...	...	...	...	...
	102nd	...	...	...	112	86	...	...	...	...	...
	62nd	...	...	...	...	131	103	108	83	...	...
	1-17th	...	...	...	...	...	133	98	116	86	...
	40th	...	...	...	...	...	...	...	...	134	...

* Only one wing from 1866.

While the previous table showed a diminution in the annual numbers of affected stations, this shows a corresponding diminution in number of affected regiments; but it also shows a marked diminution in the average annual admission rate for these. The average admission rate for the 26 regiments appearing in the column for 1865 is 118 per 1,000; that for the 18 regiments in 1874 is only 95 per 1,000.

In order, as far as possible, to complete our information, three more points remain to be considered, and these are—the general health of the regiments in the years they show high ulcer rates as evinced by their total admission rates, their history as regards admission rates from abscess and ulcer, and the nature of the locality from which they had come to any station in which abscess and ulcer prevailed among them.

The statistics show that although, as a general rule, high admission rates from the special cause concur with high general admission rates, still, as in regard to stations and years so in regard to regiments, there is no necessary coincidence; it is not invariably those years in which the regiments show highest general admission rates that they show high ulcer rates, nor those with lowest admission rates in which they show relative exemption.* All the facts go to prove the existence of some special causation beyond mere general condition as regards health.

In Table V. the stations are arranged according to the frequency with which they occur as antecedent localities—as localities in which regiments had been immediately previous to coming to the stations in which they suffered specially from prevalence of abscess and ulcer, and which may, therefore, be supposed to have exerted some predisposing or causative influence on such prevalence. Of all these localities England stands out conspicuously, occurring more than three times as frequently as any of even the highest of the others do. Owing to the vagueness of the nomenclature more cannot be said regarding this than that it certainly demonstrates the influence of previous localities on the production of the diseases included under the general term, and that it probably, partially at all events, explains the extreme prevalence of such forms of disease in stations such as Lucknow, in which regiments new to the country are frequently located. The prevalence of such forms of disease among new arrivals may also probably explain many of the cases in which low total and high special admission rates coincide.

Comparing the last two tables with one another, the influence of previous localities is also illustrated by cases such as those of the 38th in Subathoo in 1865-66, and of the 85th and 37th in Dugshaie in 1871 and 1873. In regard to the 38th in 1865, it is specially noted that many of the admissions were due to Delhi sore, the regiment having been in Delhi during the previous year, and having suffered there severely from the disease. With regard to the 85th and 37th the influence of Mean Meer is hardly less distinct. The necessity for taking the history of individual regiments into account is also very clearly brought out by the case of the 109th. It is only

* A Table illustrative of this point will be found printed in the Edition of this Report which appeared in the Twelfth Annual Report of the Sanitary Commissioner with the Government of India, page 145, 1876

during the years in which this regiment was in Mooltan that the station appears as giving a high admission rate from abscess and ulcer, and it is only in connection with it that it appears as an antecedent station.

In considering the characters of stations as illustrated by the figures regarding natives, we are free from the fallacies dependent on any such great change in climate and conditions of life as that to which Europeans are subject in coming newly to the country. The change, however, to which natives of localities far up country are exposed in coming to stations in the lower provinces is very considerable, and one

TABLE V.

Table showing the immediately previous Stations of the Regiments which furnished 70 *per* 1,000 *and upwards of Admissions from Abscess and Ulcer.*

Previous Station occurring once during the ten years.	Previous Station occurring twice.	Previous Station occurring three times.	Previous Station occurring four times.	Previous Station occurring five times.	Previous Station occurring seven times.	Previous Station occurring twenty-three times.
Abyssinia. Agra. Berhampore. Ceylon. Darjiling. Ferozepore. Fyzabad. Jhansi. Jullundur. Kamptee. Kussowlie. Meerut. Mooltan. Rai Bareilly. Sagar. Shajehenpore. Subathoo.	Allahabad. Bareilly. Dinapore. Dugshaie. Jubbulpore. Madras. Nowshera. Roorkee. Sialkote.	Benares. Delhi. Dum-Dum. Hazaribagh. Nusserabad. Rawul Pindi. Seetapore. Umballa.	Bombay Presidency. Fort William. Lucknow.	Mean Meer.	Peshawur.	England.
17	9	8	3	1	1	1

might naturally look for a result similar in kind, though perhaps not in degree, to that occurring in newly-arrived Europeans. In fact, however, no evidence of any such effect can be traced. On the contrary, the stations in Lower Bengal and Assam give an admission rate very considerably lower than that for any other area (Table II).

During the first three years of the period the admission rate was considerably higher than it has been since, due to the very high admission rates of the regiments connected with the Bhutan war. When the Eastern Frontier stations are excluded from consideration, the admission rate is very much diminished, the average for the

ten years being only 78·8, and that for the nine last years only 73·3 per 1,000.* The average, then, for the entire period is very much lower than that of the other areas, the next, that of the Punjab, being 104·3. The averages of the respective areas for the ten years are consistently higher for native than for European troops. The difference for Bengal is, however, very trifling; and if the comparison be confined to the area occupied by both sets of troops by excluding the Frontier stations, the average comes out very greatly in favour of the native troops;—the European average being 96·9, whilst that of the natives is only 78·8 per 1,000.

The following table shows the order in which the various areas range as regards both sets of troops during the first and second five years' periods included between 1865 and 1874, the Eastern Frontier being excluded:—

TABLE VI.

Showing Areas and Troops according to order of average prevalence of Abscess and Ulcer during two periods of five years.

First Period.		Second Period.	
Areas and Troops.	Rates.	Areas and Troops.	Rates.
Bengal, Natives	88·6	Hill Stations, Europeans	55·6
Punjab, Europeans	95·5	Bengal, Natives	69·0
Gangetic Provinces, Europeans	102·5	Rohilkund and Meerut, Natives	76·8
Agra and Central India, Europeans	104·5	Punjab, Europeans	78·8
Rohilkund and Meerut, Europeans	108·4	Agra and Central India, Europeans	80·4
Punjab, Natives	110·2	Bengal, Europeans	82·6
Bengal, Europeans	111·3	Rohilkund and Meerut, Europeans	92·2
Gangetic Provinces, Natives	123·7	Gangetic Provinces, Native	98·2
Rohilkund and Meerut, Natives	140·7	Punjab, Natives	98·5
Agra and Central India, Natives	161·7	Gangetic Provinces, Europeans	98·6
		Agra and Central India, Natives	135·1

* The following are the detailed Annual Rates for comparison with those including the Frontier Stations in Table II:—

Showing Low Admission Rate from Abscess and Ulcer in Bengal.

Year.	Admission rate for all Regiments except those on the Frontier.
1865	128
1866	72
1867	93
1868	94
1869	56
1870	80
1871	55
1872	66
1873	72
1874	72
Average	78·8 (or 72·3 for the last nine years).

So far as general health is concerned Bengal comes second highest in admission rate, the order being Agra and Central India, Bengal, Punjab, Gangetic Provinces, Rohilkund, and Meerut. The order by fever rate is different, being Agra and Central India, Punjab, Bengal, Gangetic Provinces, and Rohilkund and Meerut.

These periods are too short to allow of instituting comparisons on the differences presented by them, but there are some curious differences exhibited by the European and native troops in regard to some areas in both periods which are worthy of being noted. In both periods Bengal furnishes a very low admission rate for natives, whilst in the case of the Europeans it furnished the highest admission rate for the first period, and occupied a middle position in the second one. Agra and Central India, on the other hand, occupies a very different position in the scale for natives—for whom in both periods it appears as the area giving highest admissions—from what it does in the case of the Europeans, with whom it occupies a middle position for the first period, and the second exclusive of hill stations in degree of exemption in the latter one.

In comparing the admission rates of natives and Europeans, and observing the general greater prevalence of such forms of disease as are included under the head of abscess and ulcer among the latter, much influence may be, and often has been, ascribed to the injurious effects of badly fitting boots of European pattern on the unprotected feet of the natives as accounting for a great part of the prevalence of such disease among them, and for its excessive prevalence in certain stations among them as compared with the European troops. Badly fitting boots may, or rather must, form efficient exciting causes for the local development of ulcers; but the figures contained in these tables do not warrant a belief in their being endowed with any more important influence on the causation of the disease. The native troops in Bengal Proper wear boots as well as those in other parts of the country, and yet the prevalence of abscess and ulcer throughout a prolonged period remains consistently lower than that of the Europeans in these localities.

Before leaving the questions specially affecting the native troops, there are a few points in connection with the Punjab Frontier which appear to call for notice. The average admission rate for the regiments there for the ten years' period is very high, and, unlike the rest of the areas, it shows a higher rate for the second five years than for the first—in other words, it shows no evidence of any tendency to diminution in the prevalence of such forms of disease as the other areas do. This being the case, is there anything to explain the matter? Are the conditions of the area such that no improvement is possible or to be looked for? At the outset it must be allowed that the stations on the frontier are generally very unhealthy, the troops almost invariably showing a very high total admission rate. We have, however, already seen that prevalence of abscess and ulcer cannot be regarded as the direct result of general unhealthiness of a station or regiment, so that allowing it all due weight as indirectly influential, some more special condition must yet be sought for. That the excessive prevalence is really not inevitable appears probable from what we find to be the case in Mooltan, which in locality and general conditions so closely resembles the Frontier stations in many respects.

The following table shows the admission rates from abscess and ulcer for European and native troops in Delhi and Mooltan:

TABLE VII.

Admission Rates from Abscess and Ulcer in Delhi and Mooltan compared with those in their respective Provinces.

Year.	Europeans.				Natives.			
	Delhi.	Rohilkund and Meerut.	Mooltan.	Punjab.	Delhi.	Rohilkund and Meerut.	Mooltan.	Punjab.
1865	90	142·3	55	115·4	148·7	157·1	92	128·0
1866	107	112·6	80	99·9	244·8	174·4	151	133·0
1867	68	90·0	48	71·0	135·9	107·8	150	110·1
1868	66	98·0	125*	97·2	47·6	86·1	111	98·6
1869	92	99·1	182*	94·0	128·8	78·1	78	81·4
1870	55	87·6	97*	84·4	144·4	77·3	178	103·6
1871	195	113·8	66	75·5	104·7	68·1	102	118·8
1872	86	93·2	63	77·3	88·6	75·6	80	91·7
1873	50	81·6	62	77·3	63·2	79·5	109	85·5
1874	69	84·9	79	79·8	106·5	83·5	109	93·0
Average ...	87·8	100·3	85·7	87·1	121·3	108·7	116	104·3

Confining our attention at present to the figures relative to the latter station, we find that whilst the average admission rate from abscess and ulcer for native troops there is very high, approaching that of the frontier stations, and considerably in excess of the average for the Punjab, the average admission rate for European troops is low, less, as it stands, than that for the Punjab, and very greatly less than that when the rates are corrected by excluding the excess due to one regiment, the 109th. There must be something connected with the conditions of the two sets of troops quite apart from the general conditions of the station as to climate, &c., to account for this striking difference.

It is a matter of interest in connection with this subject to compare the admission rates of the regiments on the North-East and North-West Frontiers with those of the troops immediately adjoining them in locality. In both cases the Frontier rates are excessive as compared with the others. Taking the averages for the last five years, we find them to stand thus:

North-East Frontier.	Bengal.	North-West Frontier.	Punjab.
97·4	69·0	146·8	98·5

These figures are very curious. Of course it cannot be maintained that the exact forms of disease are identical for the four areas, as the nomenclature is too vague to allow of any determination of the extent to which this is the case; but the

* These high figures are entirely due to the 109th Regiment. The Artillery for the same years gave 69, 82, and 65 per 1,000, which would reduce the average to 66·9.

The facts with regard to the 109th appear parallel with those of the 38th in Subathoo.

The figures for Europeans in Delhi and Mooltan are below those of their respective districts. For natives the reverse is the case. It cannot then be any general condition that is the cause; it must be one to which the natives are more exposed.

figures at all events show that, as a feature common to them, Frontier stations present an excessive prevalence in the forms of disease included by the terms abscess and ulcer. It would be hard to find any two regions more opposed to one another in many respects than the North-East and North-West Frontiers. The stations present hardly any common features, save that they are generally unhealthy; that special forms of disease, such as abscess and ulcer, are very much more prevalent in the troops there than in neighbouring areas; and that no European troops are present in them. How far this last fact may explain the excessive prevalence it is impossible to determine definitely at present; but it appears probable that less attention to sanitary improvement at places where no European troops are quartered, may, perhaps, account for it.

The previous tables have shown that the prevalence of abscess and ulcer is dependent on some cause distinct from the mere general condition of health of troops; that general unhealthiness does not necessarily cause great prevalence of such disease, nor healthiness necessarily secure exemption: it now remains to be seen to what extent the statistics are capable of affording more definite information. In proceeding to examine the possible special causes for the prevalence more closely, it appears that one condition or set of conditions on which importance has frequently been laid, namely, those giving rise to the so-called malarial fevers, may be set aside. The figures clearly show that malaria, as indicated by prevalence of such fevers, is not the determinant cause of the prevalence of abscess and ulcer. This cannot be better illustrated than by comparing the stations of Lucknow and Nowshera.

TABLE VIII.

Comparison of Admission Rates from Fever and Abscess and Ulcer of Europeans in Lucknow and Nowshera.

Year.	Lucknow.			Nowshera.		
	Total Admission rate.	Fever.	Abscess and Ulcer.*	Total Admission rate.	Fever.	Abscess and Ulcer.
1865	1184·7	382·3	91	1910·0	1067·1	56
1866	1230·3	198·1	100	2282·3	1202·4	81
1867	1143·2	186·2	88	1452·1	959·0	80
1868	1223·4	153·9	95	1522·6	929·5	69
1869	1204·0	211·1	111	2167·6	1506·6	32
1870	1410·8	376·5	112	2762·9	2136·1	55
1871	1094·4	219·0	103	3395·5	2591·4	43
1872	1496·3	185·5	103	2434·3	1588·7	76
1873	1296·7	336·6	110	2028·4	1194·3	58
1874	1298·0	310·8	48	1870·5	1189·7	79
Average	1258·1	246·0	96·1	2182·6	1256·4	62·9

* Calculated from Infantry Regiments only.

As far as European troops are concerned, the illustration is liable to a fallacy, owing, as has been previously noted, to the excessive liability of new arrivals in the country to abscess and ulcer. Taking the native troops, however, this is avoided, and on doing so we arrive at similar results. During the six years from 1869, from which year Nowshera was occupied by native troops, we find the results as below:

	Lucknow.	Nowshera.
Average fever rate for six years	453·3	1031·7
Average abscess and ulcer for six years ...	128·3	94·1

The same thing is demonstrated on a large scale by the statistics of the European Armies of Madras and Bengal, as is shown in the following statement relative to the four years from 1871 to 1874:

TABLE IX.

Admission Rates of European troops in the Armies of Bengal and Madras compared.

Year.	Army of Bengal.			Army of Madras.		
	Total.	Fevers.	Abscess and Ulcer.	Total.	Fevers.	Abscess and Ulcer.
1871	1507·7	590·5	86·3	1193·2	167·1	122·4
1872	1514·4	495·9	80·2	1357·4	267·7	123·6
1873	1349·8	516·1	80·9	1270·6	236·8	108·7
1874	1443·8	552·8	84·7	1143·9	187·1	103·0

The question of the influence of water in producing such diseases will be more fully entered upon in connection with the special facts regarding Delhi, and our own observations there; but the general statistical results regarding the prevalence of them over the country at large go so far, at all events, as to give no support to theories which regard the organic impurities of water as of paramount importance. There is nothing in the general distribution of the disease as illustrated by these figures to justify any such views, and there are some facts, such as the persistent and marked comparative exemption of the native troops in Lower Bengal, which seem entirely opposed to them.

2.—*Facts regarding the occurrence of Sores among the troops at Delhi.*

The special facts relative to the occurrence of abscess and ulcer among troops in Delhi remain to be considered. The following table (Table X) shows the total admission rates of the Native and European troops, with the ratios contributed by the main causes of admissions. The portion referring to the Europeans begins from the year 1859, that for Natives only from 1864, as that is the earliest date for which detailed information regarding them is attainable.

TABLE X.

Admission rate in Delhi per 1,000.

EUROPEAN TROOPS.

Year.	Cholera.	Heat Apoplexy.	Fevers.	Dysentery.	Diarrhœa.	Hepatitis.	Ophthalmia.	Rheumatism.	Venereal diseases.	Diseases of respiratory organs.	All other causes.	Total.	Abscess and Ulcer.
1859	2·1	6·4	665 7	67·9	104·3	41·4	100·0	90·7	539·3	80·0	551·4	2249·2	...
1860	1·9	...	647·1	56·0	113·9	48·5	82·2	165·2	413 6	77·5	633·1	2239·0	...
1861	74·5	...	766·6	136·6	247·6	57·7	119·8	63·0	656·0	45·2	394·0	2561·0	...
1862	...	1·7	958·1	49·6	87·1	50·4	94·0	59·0	377·0	51·3	483·7	2211·9	...
1863	...	7·5	1175·4	49·7	158·4	55·3	79·7	85·4	294·5	105·1	561·9	2569·3	...
1864	...	2·1	904·6	46·7	76·8	77·8	76·8	61·2	379 6	70·5	681·5	2377·6	...
1865	...	9·2	594·5	39·2	66·8	25·3	13·8	78·4	345·6	80·7	336·4	1589·9	90
1866	2·7	2·7	397·4	42·1	50·0	42·1	36·8	71·0	355·2	92·1	315·8	1407·9	107
1867	2·9	...	720·8	65·5	136·8	54·1	14·2	111·1	165·2	74·1	324·8	1669·5	68
1868	...	10·0	1179·4	29·9	83·1	122·9	23·2	122·9	166·1	156·1	501·7	2395·3	66
1869	...	24·9	1309·4	71·8	99·4	74·6	13·8	77·4	127·1	121·5	428 2	2348·1	92
1870	...	5·9	731·6	59·0	53·1	67·8	50·9	61·9	277·3	85·6	271·4	1619·5	55
1871	...	...	839·7	62·2	110·0	19·1	12·0	71·8	308·6	55·0	540·7	2019·1	195
1872	...	1·8	1057·1	47·9	117·9	75·5	14·7	103·1	195·2	70·0	430·9	2401·4	86
1873	...	6·3	664·6	48·5	78·1	90·7	21·1	57·0	128·7	97·0	377·6	1569·6	50
1874	...	5·6	1282·8	13·1	78·7	18·7	11·2	76 8	108·6	82·4	353·9	2031·8	69

NATIVE TROOPS.

Year.	Cholera.	Fevers.	Dysentery.	Diarrhœa.	Hepatitis.	Spleen.	Ophthalmia.	Rheumatism.	Venereal diseases.	Diseases of respiratory organs.	All other causes.	Total.	Abscess and Ulcer.
1864	...	954·3	87·7	21·9	...	16·5	11·0	51·2	43·9	67·6	1252·3	2506·4	...
1865	...	432·9	35·7	25·5	5·1	...	13·6	57·7	39·0	50·9	419·4	1079·8	148·7*
1866	...	335·5	4·8	34·8	...	...	23·7	63·3	26·9	33·2	392·4	914·6	244·8
1867	1·6	635·9	34·0	68·0	...	11·3	9·7	29·1	16·2	24 3	228·1	1058·2	135·9
1868	2·9	1028·8	33·1	36·0	...	40·4	2·9	31·7	23·1	15·8	344·4	1559·1	47·6
1869	...	1189·7	59·6	51·7	...	28·2	7·8	23·5	15·6	29·8	473 4	1879·3	128·8
1870	1·5	1620·5	69·3	54·2	3·0	9·0	1·5	37·7	9·0	31·6	238 0	2075·3	144·4
1871	2·9	1114·5	47·8	30·4	1·5	1·5	5·8	36·2	10·1	23·2	279·7	1553·6	104·7
1872	...	791·2	68·6	35·1	...	7·6	10·7	36·6	41·1	18·3	192·1	1404·0	88·6
1873	...	925·0	36·8	27·6	...	4·6	9·2	12·2	16·8	26·0	154·7	1212·9	63·2
1874	...	961·7	51·1	17·6	3·2	12·8	9·6	46·3	30·3	102·2	246·0	1480·8	106·5

An additional column is added in both cases from the year 1865, in which the rates of admission from abscess and ulcer are stated separately in place of being included along with others under "All other causes."

Most of the features presented by this table are just repetitions on a small scale of those shown in the previous tables in regard to the distribution and prevalence of diseases of this class over the country at large, such as the general tendency to diminution of the special admission rate with diminished total rate, the absence of any necessary

* These figures are derived from Dr. Bryden's statistical Tables. They refer to Infantry Regiments only: no particulars regarding the detachments of Cavalry being attainable.

coincidence between high general admission rate, or high fever rate, with high ulcer rate in any special year, etc. The most important thing in the table is the demonstration it contains of the existence in Delhi of a much higher ulcer rate for Native than for European troops, the average rates for the ten years' period from 1865 to 1874 being—

European Troops.	Native Troops.
87·8	121·3

The previous tables have shown that such a relation between the rates is not necessary or invariable; in Bengal, for example, we found the reverse to be the case, and we are therefore justified in coming to the conclusion that there is something special in the conditions of the Native as compared with the European troops in Delhi, which renders them specially liable to such disease.

It is interesting to note the parallel exhibited by Mooltan to Delhi in regard to the occurrence of abcess and ulcer among European as compared with Native troops: *vide* Table VII. Both stations show an admission rate from abscess and ulcer considerably below the provincial average for Europeans, and considerably in excess of the same for natives.

The next and last table (No. XI.) shows the total admission rates, and those from fever and abscess and ulcer, of each body of troops for each year of the ten years' period.

TABLE XI.

Total Admission Rates, and those from Fevers, and Abscess and Ulcer, of the individual Regiments, etc., at Delhi since 1865.

Year.	Regiment, etc.	Total Admission Rate per 1,000.	Abscess and Ulcer per 1,000.	Fevers per 1,000.
1865	98th Regiment, Wing	1580·0	93·9	618·1
	25th Native Infantry *	970·0	148·7	382·9
1866	98th Regiment, Wing	1230·0	60·1	322·7
	XXV Brigade, 2nd Battery, Royal Artillery ...	1660·0	328·3	447·1
	25th Native Infantry	910·0	244·8	335·4
1867	79th Regiment, Wing	1950·0	50·1	829·4
	XXV Brigade, 2nd Battery, Royal Artillery ...	1480·0	158·7	428·5
	25th Native Infantry	1000·0	135·9	558·2
1868	79th Regiment, Wing	1986·0	63·1	889·4
	XXV Brigade, 2nd Battery, Royal Artillery ...	2204·1	61.2	632·6
	17th Native Infantry	1460·0	47·6	1030·7
1869	79th Regiment, Wing	2262·8	89·7	1237·1
	XXV Brigade, 2nd Battery, Royal Artillery ...	2636·3	127·2	1400·0
	17th Native Infantry	1780·0	128·8	1202·2

* No separate details are given regarding the detachments of Native Cavalry at Delhi, the returns regarding the men there being included in those of the regiment to which they belong.

TABLE XI.—(*Continued.*)

Total Admission Rates, and those from Fevers, and Abscess and Ulcer, of the individual Regiments, etc., at Delhi since 1865.

Year.	Regiment, etc.	Total Admission Rate per 1,000.	Abscess and ulcer per 1,000.	Fevers per 1,000.
1870	103rd Regiment, Wing	1543·7	47·6	2710·3
	XXIV Brigade, 1st Battery, Royal Artillery ...	1876·7	82·1	876·1
	17th Native Infantry	2111·8	144·4	1625·7
1871	109th Regiment, Wing	2162·8	208·5	922·8
	XXIV Brigade, 1st Battery, Royal Artillery ...	1797·5	126·5	455·6
	17th Native Infantry	1577·8	104·7	1146·0
1872	109th Regiment, Wing	2578·6	102·5	1166·2
	XXIV Brigade, 2nd Battery, Royal Artillery ...	1970·6	19·6	676·4
	20th Native Infantry	1359·5	88·6	752·5
1873	109th Regiment, Wing	1279·7	54·4	480·1
	XXIII Brigade. 2nd Battery, Royal Artillery ...	2242·1	31·5	848·2
	20th Native Infantry	1123·1	63·2	836·9
1874	55th Regiment. Wing	1934·6	59·0	1263·7
	XXIII Brigade, 2nd Battery, Royal Artillery ...	1741·6	123·5	943·7
	20th Native Infantry	1407·2	106·5	879·7

3.—*The special local conditions at Delhi possibly bearing a causative relation to the Sore: the Water-supply.*

Having, then, ascertained that there must be some local condition in Delhi tending to produce "abscess and ulcer," and a condition to which the native troops are more exposed than the Europeans, we have next to endeavour to ascertain to what extent these statistics indicate the occurrence of the special form of disease known as "Delhi sore" among the troops, and whether it occurs more among the native than the European troops.

Although the existence of a peculiar form of sore in Delhi has been long well known, it was, as already mentioned, only after the mutiny that the occurrence of the disease among the troops stationed there attracted any special attention. Previous to that period the greater part of the troops in the station were located in the old cantonment at some distance from the city, and it is a well ascertained fact that there is but a very slight tendency to the development of the affection in people living there as compared with those within the city walls. The troops occupied the interior of the city from the latter part of 1857, and from that date the prevalence of the disease among them began, and appears to have gone on steadily until it reached a climax in the year 1864. During that year the regiments at the station were the 38th European and the 4th Native Infantry, and the disease prevailed among them to an almost incredible extent. Among the Europeans especially, the prevalence was so great, that 40 and 70 per cent. are said to have been affected. The evil was of such serious

magnitude and such a formidable cause of interference with the efficiency of the troops, that a Committee was convened in January 1865 to investigate the matter and to determine on measures for the diminution of the disease. The Committee recommended various sanitary measures, the most important of them bearing on the improvement of the water-supply of the troops, and especially of the European troops. Previous to that date the water-supply of the Europeans had been solely from wells.

During 1865 the measures recommended by the Committee were put into effect, the bathing and drinking water of the Europeans was obtained from the river Jumna as much as possible, and the drinking water was first boiled and then filtered. The measures regarding the water-supply of the native troops were apparently directed, as has always been the case on occasions demanding improvement in it, to putting the branch of the Jumna Canal which runs through the city, from which they can obtain a supply, into good order; but attention was also paid to cleaning wells, etc. During 1865 there were some cases of the disease in the 98th Regiment and the 25th Native Infantry, but the number was relatively very small; so few, indeed, and occurring so late in the year, that it was reported on the 4th September that not a single undoubted case had occurred either among natives or Europeans. Both regiments were, no doubt, new to the station, so that much of this sudden disappearance of the disease is to be ascribed to want of time for its development; still it was during the first and only year of the 38th's location in Delhi, 1864, that it suffered so excessively.

During 1866 there is no special notice of the occurrence of Delhi sores among the troops; and in so far as the European regiment was concerned, the admission rates for abscess and ulcer in that year were so low, that the disease may be assumed not to have prevailed to any great degree. The battery of Artillery and the 25th Native Infantry, however, show excessive admissions for the same year. During 1867 the European troops were supplied with drinking water from the Jumna and the Putthur Ghuttee well,—the wing of the 79th drawing their water from the former, and the battery of Artillery from the latter source. The supply for the natives was obtained, as before, from the canal and from wells. Many of the men obtained their water from the Khyrattee Gate well; this water was of very bad quality, and caused dyspeptic symptoms and diarrhœa in those using it. A certain number of the men, then as always, no doubt went to the river for water, but the distance at which the Jumna lies from the lines—$\frac{3}{4}$ths of a mile—naturally prevented its general use. The medical officer of the 25th Punjab Native Infantry, writing in 1867, says "the canal water is of fair quality, but that obtained from the Khyrattee Gate well is bad. I have observed an increase in the number of Delhi sores when the canal supply was stopped, and also a tendency to spread in those sores which were healing." Turning to Table XI, we find that the admission rate of the wing of the 79th, which had only arrived that year in Delhi, from abscess and ulcer is very low, but that the rates furnished by the Artillery and 25th Native Infantry are again very high.

During 1868 there were a considerable number of cases of Delhi sore in the wing

of the 79th,—57 cases and 9 suspicious cases having occurred between December 1867 and February 1869, according to Dr. A. Smith. These would appear to have chiefly occurred towards the latter part of the year, as in February 1868 the Quarter Master General reported that Delhi boils seemed to have left the garrison. The water for ablution supplied to the Europeans was up to this date obtained from the wells in the Fort. During the same year, 1868, the Medical Officer of the 17th Native Infantry reported that "the supply of water was irregularly given to the 17th Regiment, and sometimes altogether stopped. As the wells in the lines supply water only fit for ablution, the men are obliged to go to the river for drinking water;" and that "at all times the water-supply of the regiment is precarious." The admission rates from abscess and ulcer in all three bodies of troops were very small for 1868, that of the 17th Native Infantry, which had arrived in the station that year, being exceptionally so.

During the course of 1869 cases of Delhi boil continued to occur among the wing of the 79th. The precise number of cases is not mentioned in any of the reports to which we have had access, but the admission rate from abscess and ulcer is considerably higher than it had been during the two previous years. The admission rate of the Artillery was also high. No special information regarding the water-supply for the year is given, so that it may be presumed to have remained in the same state as before. With regard to the natives, the complaints regarding the water-supply are repeated; the scanty and irregular supply derived from the canal and the brackish nature of the wells in the lines being again commented upon. The supply from the canal is stated to have been regular and abundant for some months, but it is pointed out that this improvement is necessarily only of a temporary nature, as the demand on the canal for agricultural purposes during the hot weather must put an end to it. No special reference is made to Delhi sores, but the admission rate of the regiment from abscess and ulcer is high, being nearly three times as great as during the previous year.

In 1870 the admissions from abscess and ulcer in the wing of the 103rd were very few, and those of the Artillery, a new battery, much lower than they had been in 1869. In the medical report regarding the 17th Native Infantry various points in connection with the state of the lines are noticed. The advantage of the shade afforded by the numerous *pipul* and *neem* trees in shading the lines is noted, but there are again complaints regarding the water-supply. The distance of the Jumna is said to form the great drawback to its being generally employed by the men, and it is mentioned that the wells are used "readily enough for some time after canal water has been let into them." Thirty-eight cases of Delhi boil were treated during the year, "about as many as in the preceding year, but there are double that number of men doing their duty in the lines who have these sores, chronic and painless." The admission rate from abscess and ulcer was again high, considerably in excess of that for the previous year.

In regard to the European troops, we have been able to obtain no further definite information with reference to the occurrence of Delhi sores, beyond the fact that at

the end of August 1873 it is reported that there were not then, and had not for some time been, any cases of Delhi boils amongst them.

In 1871 the 109th Regiment gave a very high admission rate from abscess and ulcer—the highest, in fact, given by any body of European Infantry in Delhi during the entire ten years' period. The regiment arrived in the station from Mooltan in that year; in the year following it again furnished a high though diminished admission rate, and only in the third year of residence did it come down to a low figure. This is just the reverse of the phenomena which appear usually to occur with regiments coming newly to Delhi. We have been unable to obtain any more definite information regarding the nature of the cases causing the admissions, but it is questionable how far they ought to be credited to Delhi. The regiment throughout the entire period in which it appears in our tables was very unhealthy, and, as we have seen, is the only body of European troops which furnished high admission rates from abscess and ulcer in Mooltan. The admission rates given by both the 109th and the Artillery in 1873 are very low. In 1874 a wing of the 55th was quartered at Delhi. The rate from abscess and ulcer furnished by it was low, but that of the Artillery, a battery in its second year, was high. At the time of our visit to Delhi in the early part of 1876, Delhi boil was, and had for some time been, practically unknown among the European troops.

Returning now to the native troops. During 1871 the 17th Native Infantry continued to occupy the station. The water-supply remained unchanged. Twenty cases of Delhi boil were admitted into hospital, "but that number represents only a portion of the men who suffered" from the disease. The admission rate from abscess and ulcer was again high, although very considerably lower than in the previous year. In 1872 a fresh regiment—the 20th Native Infantry—came. The Medical Officer reports that "the canal water was allowed to flow into two wells in the lines," and "the mixed water used by the men for drinking purposes was well liked." Some of the men, as usual, went to the river for drinking water, "but owing to its distance, this was not common." The admission rate from abscess and ulcer was for native troops in Delhi comparatively low. No cases of Delhi sore occurred, except in one of the officers. During the following year six cases of Delhi sore were admitted from the same regiment, but "a great many men who had them were quite able to attend to their duties, and only presented themselves occasionally at hospital as out-patients." The admission rate from abscess and ulcer is low.

In 1874 the 20th Native Infantry remained in Delhi, and fifteen cases of Delhi boil were admitted into hospital. The indifferent quality of the water-supply is again complained of. The admission rate from abscess and ulcer was high, more than 40 per 1,000 higher than in the previous year. In January 1875 the 33rd Native Infantry arrived in the station, and during that year remained free from Delhi sores. The water-supply of the lines was, as usual, dependent on the canal and the wells, until towards the close of the rains, when the canal became silted up in consequence

of the excessive floods occurring at that time. It remained closed until the hot weather of 1876, and during the interval the only sources of water-supply open to the men were the wells in the lines, or the river. No cases of Delhi sore occurred during 1875, but in the spring of 1876 cases began to present themselves, and up to date nine cases have been admitted for the year. This number, of course, does not necessarily indicate the absolute number of cases in the regiment, as it has been already seen that many who suffer are not unfit for the performance of their duties, but only receive treatment as out-patients, or, as is often the case, prefer doctoring themselves with their own nostrums.

These are the principal facts which we have been able to ascertain regarding the prevalence of Delhi sores among the troops. The only other circumstance worthy of note as bearing on the subject is the fact that, during the period in which the disease was so excessively prevalent, the detachments of Cavalry located at the Lahore and Cabul gates, and obtaining their water-supply from wells outside the city walls, are stated to have showed a marked exemption from the disease.

So far as our information goes, therefore, it would appear that the troops whilst in the Old Cantonment suffered little; that between 1857 and 1865 Europeans and natives alike were very subject to the prevalence of Delhi sores among them, the Europeans, if anything, suffering more severely than the natives, and some bodies of natives escaping almost entirely; that subsequent to 1865 there has never been the same prevalence, but that the diminution in the prevalence of the disease has been much more marked and persistent in the case of the European than in that of the native troops.

The suddenness of the fall from excessive prevalence is very remarkable in the case of the European Infantry, and must, so far as we can see, even allowing for the influence of change in the bodies of troops in the station, have been due to some sudden improvement in their sanitary conditions. No such sudden or persistent change is perceptible in the case of the natives, although with them also there has been a considerable diminution in the prevalence of the disease.

Taking these facts into consideration, there appears little doubt that the views which regard the nature of the water-supply as the immediate cause of the occurrence of the disease are well founded. We know that previous to 1865 the water-supply of the troops, save of some isolated detachments, such as the Cavalry at the Lahore and Cabul gates, was very bad. That of the European was really worse than that of the native troops, the former being dependent on the wells within the fort, the latter having a partial, though very insufficient and irregular, supply from the canal, and being, moreover, to some extent in the way of using the river water. With 1865 the conditions were reversed; river water being supplied as far as possible to the Europeans, whilst the supply for the natives was unchanged, save in so far as more attention was paid to rendering the supply from the canal efficient. Since that date constantly increasing care has been devoted to the water-supply of the

Europeans; the use of well water for drinking purposes has been entirely abandoned, and additional care is taken to secure abundant water from a clean portion of the Jumna. No such improvement has been made in the native water-supply: in fact, up to the present time it seems to remain in much the same state as in 1865. The parallelism between the facts regarding the occurrence of the disease and the nature of the water-supply appears to be incontestable. The question of the influence of the water-supply will be further discussed in a separate chapter.

4.—*Facts regarding the occurrence of Sores among the city population of Delhi.*

It is not easy, or even possible, to obtain definite data in regard to this point. It has been affirmed that the disease has diminished very much of late years, and it very probably may have done so in connection with the general sanitary improvements of the town—improvements which, it would appear, are in great measure due to the representations made by Lord Mark Kerr. The following statement, giving the number of cases treated at the city dispensary during the years 1873-74-75, shows, however, that the disease has by no means disappeared:

Number of cases of Delhi sore treated at the dispensary.

1873	.	.	95	1874	.	.	55	1875	.	.	84

These numbers are small, but they can be taken as no index of the prevalence of the disease, as the sores are of so chronic and painless a character, and cause so little inconvenience, that often either no treatment at all is adopted, or recourse is had to native remedies and nostrums of various kinds, which are commonly administered by the city barbers.

The same source of fallacy holds good in regard to attempts at estimating the prevalence of the disease in the small towns and villages in the neighbouring district, That it does occur in such places we satisfied ourselves by personal inspection, and had a practical demonstration of the unsatisfactory nature of the information to be derived from dispensary returns, in encountering cases of the disease in the streets of a town the existence of which were totally unknown to the local native doctor.

CHAPTER III.

THE INGREDIENTS IN THE WATER-SUPPLY OF DELHI WHICH APPEAR TO FAVOUR THE DEVELOPMENT OF SORES.

THE result of our inquiries, so far as we have hitherto described them, has been to localise the cause productive of "Delhi sores" to the water-supply, and we have now to consider to what extent the microscopical and chemical examination of the water itself justifies such a conclusion—to what extent it possesses peculiar characters.

The microscopic features of the waters in question may be dismissed with a few

words, as, so far as our own observations went, there was nothing to be detected which could in any way be connected with the production of any cutaneous affection akin to that under consideration.

The chemical examination, however, was suggestive. Bearing in mind what has already been stated regarding the geographical distribution of "sores" in India, it may be reasonably inferred that the organic impurities, as such, may be set aside, for the water of Delhi assuredly is by no means exceptionally bad in this respect. On the contrary, the quantity of unoxidised organic matter is, in most instances, small in the water supplies most resorted to by the population, and not to be compared with the large quantities commonly presented in the water tanks of places such as Calcutta and other cities in the Lower Provinces, where Oriental sores are practically unknown. Of this we satisfied ourselves by means of special distillations of numerous samples of water in accordance with the principles laid down by Messrs. Wanklyn and Chapman, the details of which, however, need not be recorded here, seeing that our object is not to report upon the local water-supply.

The results of the oxidation of organic substances in the form of nitrates and nitrites have been shown by all our analyses to be present in very large quantities, and are associated with a marked quantity of chlorides. So saline is the water in certain wells, that it cannot be even employed to water plants.

So far the result of our analyses has been substantially in accordance with those of former observers; but here the agreement ceases, for, according to them, the water of the Delhi wells presented no striking peculiarity in regard to hardness, whereas we found the waters as a general rule excessively hard, and in some cases almost unprecedentedly so.

We append a table giving the estimates of the "total" hardness, the "permanent" hardness, and the amount of chlorine; the last-named calculated in grains per gallon of chloride of sodium in a number of the wells in and around Delhi, as well as of a few samples of water (Nos. 23 to 28) which we collected in three towns in the Delhi district, at a distance of 10 to 25 miles from the city itself.

As is well known, the process generally adopted (Clarke's) for determining the hardness of a water may very readily give rise to fallacy owing to the presence of magnesian salts, unless special attention is devoted to the point; and it is doubtless due to this, in a great measure, that the hardness of the water has been so largely under-estimated. We believe that our figures may be accepted as correct; they give the result of, in most instances, two or three distinct determinations specially directed for elucidating this very question.

These analyses were conducted towards the end of the dry season, when the waters were doubtless more extensively impregnated with salts than after the rainy season. With the intention of definitely satisfying ourselves as to the extent of the variation, we obtained (by the kind assistance of the Engineer to the Municipality, Mr. A. J. Devon) four more samples of water collected shortly after the cessation of the rains.

TABLE XII.

Results of the analyses of 28 samples of water in Delhi and in three adjacent towns with reference to the degree of Hardness and quantity of Chlorine.

Number.	Source of sample.	Total hardnes calculated as carbonate of lime in grains per gallon.	Permanent hardness calculated as carbonate of lime in grains per gallon.	Chlorine calculated as chloride of sodium in grains per gallon.
1	Jumna, west bank	6·65	2·10	0·98
2	„ east „	6·65	2·8	0·57
3	Canal	6·65	2·10	0·57
4	Ditto	5·6	1·75	0·57
5	Well in the lines	32·55	18·55	16·9
6	Well in the town	45·85	28·0	16·9
7	Ditto	42·35	...	25·11
8	Ditto	47·6	...	45·56
9	Ditto	179·5	162·05	176·0
10	Ditto	18·5	9·8	9·57
11	Ditto	39·55	22·05	16·19
12	Ditto	64·05	43·55	51·28
13	Ditto	15·4	...	1·79
14	Ditto	23·1	5·6	62·9
15	Ditto	52·6	...	629·0
16	Ditto	61·60	46·55	48·26
17	Well outside the walls	16·60	...	3·84
18	Ditto	20·30	...	5·48
19	Ditto	10·85	...	38·4
20	Ditto	18·55	1·05	30·4
21	Ditto	15·05	...	4·48
22	Ditto	16·80	...	10·38
23	Well at Alipur	17·85	...	4·46
24	Ditto	40·95	...	27·27
25	Well in Soneput...	51·80	13·3	157·6
26	Well in Soneput	11·88	4·9	5·48
27	Well in Faridabad	35·35	12·98	22·24
28	Ditto	22·75	9·1	5·48

TABLE XIII.

Result of analyses of some Delhi waters subsequent to the rainy season.

Number.	Source of Sample.	Total hardness calculated in grains per gallon of carbonate of lime.	Chlorine calculated in grains per gallon of chloride of sodium.	Sulphuric acid, (SO^3) in grains per gallon.	Total solids in solution in grains per gallon.
1	A well in the Dâk Bungalow compound	65·8	103·8	32·2	341·6
2	A well near the Northbrook Hotel ...	43·9	51·91	22·12	203·0
3	A well near Khela Ghât	31·9	7·27	6·58	48·2
4	A new well in the bed of the Jumna, opposite Selimgarh Fort*	26·0	12·69	5·04	46·9

* With the view to avoid the expense of making special filter-beds in connection with the proposed Water-works at Delhi, the plan of sinking wells in the bed of the river Jumna, and thus effecting the filtration of the water at its source, has been proposed. It would appear, however, from this analysis that the soil in the bed of the river through which the water percolates into the wells, instead of improving the water, tends to assimilate it to that of the wells within the town, as may be observed by comparing the results of this analysis with those of the four analyses of Jumna water from different places in Table XII.

As analyses made in an extemporised laboratory can seldom be so satisfactorily performed as when conducted with all the proper appliances, and as we were anxious that our estimates should be comparable with those of a professional chemist, we consulted Professor C. H. Wood, the Chemical Examiner to the Government, who very kindly undertook the analyses of these particular samples himself, and has favoured us with the following tabular statement of the result:

Mr. Wood writes: "All the waters, in addition to lime, contain notable quantities of magnesia. The alkaline metal present is chiefly sodium, the proportion of potassium being very small. The most noticeable feature of these waters is the large proportion of nitrates present."

On comparing the figures given in Table XIII, with those given regarding the hardness and chlorides in Table XII, it will be found that they both indicate excessive hardness as a prominent feature in Delhi waters, as well after as before the rains.

How far an excess of certain salts in a water may produce the Oriental sore is a question demanding further inquiry. What we do know at present is (1) that it is something connected with the water of the wells in Delhi which appears to determine the occurrence of the disease there; (2) that this water is characterised by its excessive hardness, and (3) by the presence in it of very large quantities of salts. It does not necessarily follow that the hardness and saline quality of the water should be the direct cause of the disease; they may be accompanied by some special compound which is the real efficient agent, but there certainly are some points which seem to indicate that the hardness of the water may be taken as an index, at all events, of its containing deleterious ingredients conducive to the development of cutaneous affections of the character of Oriental sores.

Taking the well-known fact of the absence of these sores among the population of Bengal Proper, and the figures relative to the occurrence of "abscess and ulcer," among the native troops in the same region, and comparing these with the prevalence of such forms of the disease in other parts of the country, the general fact comes out very clearly, that where the water is soft, such diseases are at a minimum, and that where it is hard, they increase in prevalence and attain a maximum in a place, such as Delhi, where the hardness of the water is excessive.*

It would be a matter of great interest to carry the analysis of this question out in detail, and to determine the question for individual towns and stations. This, however, cannot be done at present; for, on the one hand, there is a want of definite statistical information regarding the occurrence of the disease, and on the other there are no chemical data of assured accuracy regarding the condition of the water.

* It is at present impossible to proceed beyond a consideration of the more general phenomena of the distribution of the sources of the disease, as our information on the subject is of so imperfect and fallacious a nature. For example, in the table regarding European troops, Dum-Dum and Fort William occupy a very high place as stations subject to abscess and ulcer, while, as a fact, forms of diseases akin to Oriental sore are practically unknown there.

CHAPTER IV.

CLINICAL FEATURES OF THE ORIENTAL SORE AS SEEN AT DELHI.

ALTHOUGH the appearance presented by the "Oriental sore" in its advanced condition varies considerably (owing principally, it would seem, to the modes of treatment, accidental as well as intentional, to which such a condition is naturally liable), still there is a certain degree of uniformity in the appearance which it presents at the onset. It generally commences as a pinkish papule, not unlike a mosquito-bite. It may retain this aspect for several days or weeks, or merely attain a more distinctly nodular character. We have heard a patient describe this condition by comparing it to a little seed that had been introduced under the skin. In other cases the tuberculated character is less evident, but in all, so far as we have been able to ascertain, the skin becomes thin and somewhat glistening, and the vascularity of the parts beneath more evident.

It may gradually disappear without any further inconvenience, but generally it takes one of the two following courses: (1) Either the central part of the papule desquamates, and layer after layer of shrivelled epithelial scales are thrown off, unaccompanied for a long time with any perceptible secretion or distinctly marked scab; or (2) the desquamation is accompanied with a thickish secretion which forms a hard adherent scab, beneath which a red, raw surface is formed, which may or may not bleed readily on irritation, but is seldom painful.

The surface thus affected varies in extent from a few lines to one or even two inches in diameter; but the average area occupied by it is about the size of a shilling or half-a-crown. It is not localised to any particular region of the body, several parts of which may be affected at the same time. The forehead, the cheek, the wrist, the back of the hands and feet, the points of the elbows and the knees, and not unfrequently, the side of the nose between the bridge and the inner canthus, are the sites where sores are most commonly found.

A sore may start from either one or several centres, which, gradually approaching each other, eventually coalesce and become covered by a single scab. Sometimes a shiny, slightly elevated, wheal-like belt of indurated tissue may be observed to encircle the sore, covered with a thin cuticle, and presenting an appearance not unlike that of the indurated tissue forming the margins of a lachrymal sinus, or other fistulous orifice.

When a poultice is applied, the softened parts become puffy; the adherent scab, when present, becomes loosened, and the sore bulges forward, often considerably beyond the level of the surrounding parts so as more or less to resemble a boil or, even, a carbuncle. This condition is represented in the accompanying sketch—the chromolithograph of which, however, is somewhat too hard and diagrammatic (Plate XXVIII, Fig. 1). The normal colour of the scab is yellowish. Owing, however, to the various

Fig. 2.

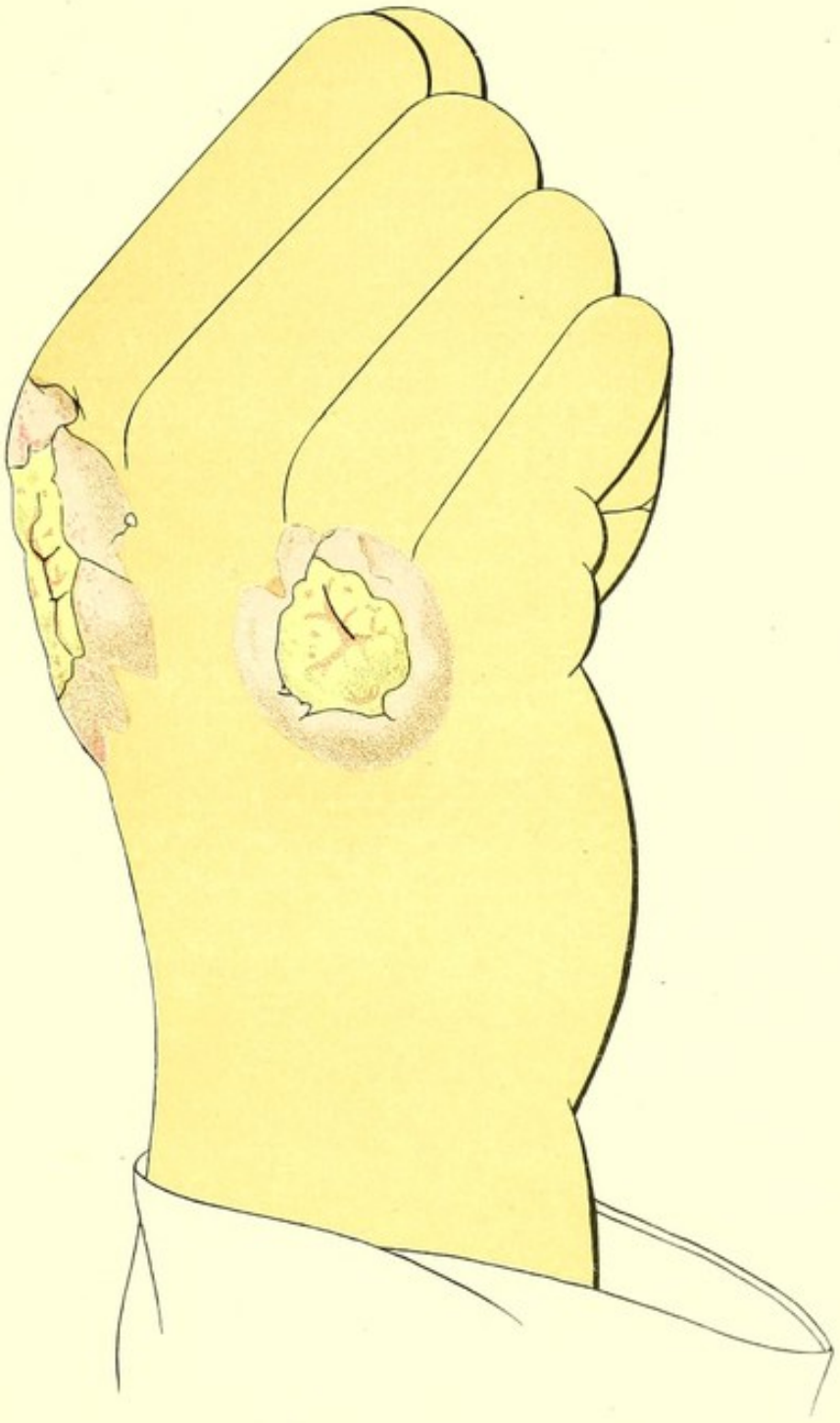


Fig. 1.

"THE DELHI SORE"

To face p. 418.

Fig. 1.—A hand with two "Sores" on dorsal surface.

" 2.—Vertical Section of "Delhi Sore" Natural size.

nostrums applied, it seldom presents its natural tint, but ranges from a greyish-yellow to various shades of black.

It is difficult to fix upon any particular age at which the sore manifests itself most frequently. From puberty to thirty may be mentioned as the time of life during which we ourselves have most frequently witnessed the disease, but we have likewise seen it in persons whose ages ranged from two to fifty-five years.

As in the case of the "Oriental sore" described in other localities and countries, so also in the sore as met with in Delhi, one of its leading features consists in the chronic course which it runs. It may last from a month or two to several years, but perhaps six to eight months may be set down as its average duration when not aggravated by improper local and other treatment. When it heals, a permanent pinkish-white or pale-yellow scar marks the site and area of each sore. Dr. C. H. Y. Godwin, in a report on the subject in 1865, thus describes the pseudo-healing process so frequently witnessed during the course of the disease, and which so often only results in disappointment: "When," writes Dr. Godwin, "commencing to heal, it does so by filling up in the centre, and not from the circumference; but the great tendency is to dry or scab over, and this leads the patient often to think that his sore has at last healed: not so, however; this surface breaks down again and again, leaving each time an ulcerated surface larger than before."

CHAPTER V.

THE PATHOLOGY OF THE ORIENTAL SORE.

As already intimated, the discussion of the different views which have been propounded in this country and in Europe regarding the significance of the various pathological appearances which the diseased tissues present in this affection forms no part of our programme, nor are we called upon to express any opinion regarding the importance to be attached to the various microscopic objects and organisms which have from time to time been described as associated with the disease, but simply to record what we ourselves have been able to see, and to limit our inferences to actual observations on the Oriental Sore as in Delhi and its vicinity.*

1.—*Examination of the Sore in situ.*

The two sores depicted in Plate XXVIII (Fig. 1) as occurring on the dorsal surface of a sepoy's hand represent the ordinary features of a developed Delhi sore as covered

* We are greatly indebted to the surgeon in medical charge of the 33rd Native Infantry Regiment (Dr. E. R. Johnson) for the active manner with which he aided us during our stay at Delhi, and for the opportunities which he so readily afforded us for the study of the complaint among the sepoys in his regiment. Assistant Surgeon Radakishen also, by the permission of the Civil Surgeon of Delhi (Dr. Fairweather), materially contributed to the furtherance of our work by collecting numerous cases of the sore for our inspection at the Charitable Dispensary, and in other ways.

by a scab, softened by the application of a poultice. These particular sores had existed from six to eight months. They are seen to be slightly elevated, and the scab sub-divided into little areas, and the whole surrounded with a glistening pinkish areola. Although in these particular instances the sores are circular, it may be mentioned that the other sores on this sepoy's body—on the elbow and hip—presented a more irregular outline.

When the crust which forms over sores of this character is carefully elevated, the raw surface below it will be found, as a general rule, to consist of numerous pinkish nodules of vascular tissue, the tips of which are very commonly indicated by the existence of dark specks visible to the naked eye. In some cases the sores look as if they had been peppered over with such little granules. The microscope reveals that the darkly pigmented particles are due to minute extravasations of blood, the corpuscular elements of which have for the greater part become broken up.

On drawing the margins of a thin cover-class very gently across the sore for the purpose of scraping off a little of the moistened surface for subsequent examination, it is seldom that any pain is complained of, nor does hæmorrhage usually ensue. The secretion thus removed and submitted to microscopic examination is found to contain a few red blood corpuscles and a large number of granular, lymphoid cells averaging from $\frac{1}{4000}''$ (= ·006 mm.) to $\frac{1}{3000}''$ (= ·008 mm.) of an inch in diameter (Fig. 16).

Fig. 16.—Cells from the free surface of a "Delhi sore" × 850. (Hartnack's Obj. No. 9—immersion.)

Fig. 17.—As Fig. 16, after the addition of acetic acid × 850.

Fig. 18.—The nuclei which have become free owing to the destructive action of acetic acid on the corpuscles in Figs. 16 and 17 × 850.

Liquor potassæ dissolves these cells completely. *Acetic acid*, however, clears up the cells and brings to view the existence of either one, two, or more nuclei (Fig. 17). After prolonged action of the acid the corpuscles will be found to have become in great part broken up, the nuclei alone remaining to mark the site occupied by the corpuscle (Fig. 18).

Occasionally yellowish-white little bodies of about the size and form of millet seed may be detected, and may be readily picked out with a hand lens. They average about $\frac{1}{62}''$ (= ·4 mm.) in length by $\frac{1}{100}''$ (= ·25 mm.) in width. This is the average of three measurements. They are of somewhat shaggy outline, and may be crushed between the cover-glass and the slide by the application of a little, firm

continuous pressure. In the accompanying woodcut (Fig. 19) one of these miliary particles is depicted as seen under a comparatively low power. It is manifestly an aborted hair follicle, a portion of the disintegrated hair being plainly distinguishable in the centre of the mass. The adjoining figure represents the same millet seed-like particle as seen after being crushed beneath the cover-glass. The application of a higher power made it evident that we were dealing with disintegrating epithelial elements.

It is, however, by no means invariably possible to distinguish the remains of a hair in these little particles, and sometimes it seems as if they consisted of firmly compressed plugs (*comedones*) thrown out of the sebaceous follicles, or even of the disintegrated cast-off follicles themselves. As far as our experience goes, the presence

Fig. 19.—Miliary particle from the surface of a "Delhi Sore" × 60.
Fig. 20.—As Fig. 19 crushed between the cover-glass and slide × 60.

of these little miliary particles of various composition is far from being a prominent feature in the generality of cases.

No other objects presented themselves to us as existing on the surface of the sores, or embedded in the secretion which covered it. We examined most carefully numerous sores in order to satisfy ourselves very thoroughly regarding this point, but nothing which appeared to us to be worthy of note could be found that could not be referred to contact with extraneous substances. Of the latter, however, endless objects might have been described, as may readily be inferred, considering the liability of such a surface to dirt.

Miliary particles, such as we have just described, are common to numerous cutaneous affections; and with regard to the limphoid corpuscles, it may be, we think, safely said that they are indistinguishable optically from similar bodies encountered in numerous other allied morbid conditions. The evidence afforded by

the effect of the addition of re-agents, also, is purely negative for diagnostic purposes, except in so far as to be amply sufficient to show that they have no cell wall composed of cellulose or any material of a similar nature.

2.—*Examination of extirpated sores.*

As already observed, the sore is in most cases readily movable above the subcutaneous tissue, and when extirpated, especially after the previous application of a poultice for some hours, a considerable quantity of serous effusion may be found to have accumulated around the base. A representation of the appearance of the surface exposed by a vertical section of a sore removed in this manner will be found in Plate XXVIII, Fig. 2. The specimen here delineated measured something less than an inch in diameter at the base, and about a third of an inch in depth. It may, however, be remarked that the vertical measurement was perceptibly increased after the application of a poultice.

The principal features manifested by a close examination of the section of a recent but fully developed sore, with the naked eye and by means of a hand lens, are the following (*vide* Plate XXVIII, Fig. 2):

Taking the tissues from above downwards, we observe (supposing, as in the present instance, the sore not to have advanced to the condition of an extensive raw surface)—(1) erosion and tenuity of the cuticle along the uppermost surface of the sore, but a thickening of it on either side of this part, which thickening extends but a short distance beyond the area occupied by the diseased tissue; (2) deepening of the Malpighian layer, and enlargement of the papillæ; (3) pink striæ directed vertically towards the uppermost part of the preparation, manifestly congested vessels proceeding towards the papillæ; (4) a line of glistening decussating fibres of connective tissue of a slight bluish tint running parallel with the base of the sore and about mid-distant between the surface and the base; (5) the even line of the base of the preparation, showing its freedom from any organic connection with the subjacent structures, other than the ordinary cellular tissue with its usual vascular and nervous concomitants; and (6) in some places along the base slightly mammillated elevations projecting a little beyond the level of the base of the growth, directed towards the normal tissue below the sore.

In order to make this description and the anatomical details which follow more readily comprehended, we direct attention for a moment to the accompanying illustration (Fig. 21) of a vertical section of normal skin. The structures therein depicted have all been drawn to scale by means of a camera lucida; and although the illustration is based on three different hardened preparations made from consecutive sections of a fragment of skin removed from midway between the ear and the eye, nevertheless the relations of the parts to each other and the distance of the various structures from the surface have been kept, so that the drawing may be compared

with Fig. 22 on next page, which represents the changes which occur in the different parts of the skin in Delhi sore.

The letters *a*, *b*, *c* correspond to the three principal layers of which the skin consists. The horny (*a*) and the mucous layers (*b*) of the epidermis form what is usually implied by the cuticle; the upper layer consists of hardened epidermic scales, and follows a course almost parallel to the surface, but the lower layer not only consists of more distinctly cellular elements (the prickly-cog-wheel aspect of a great

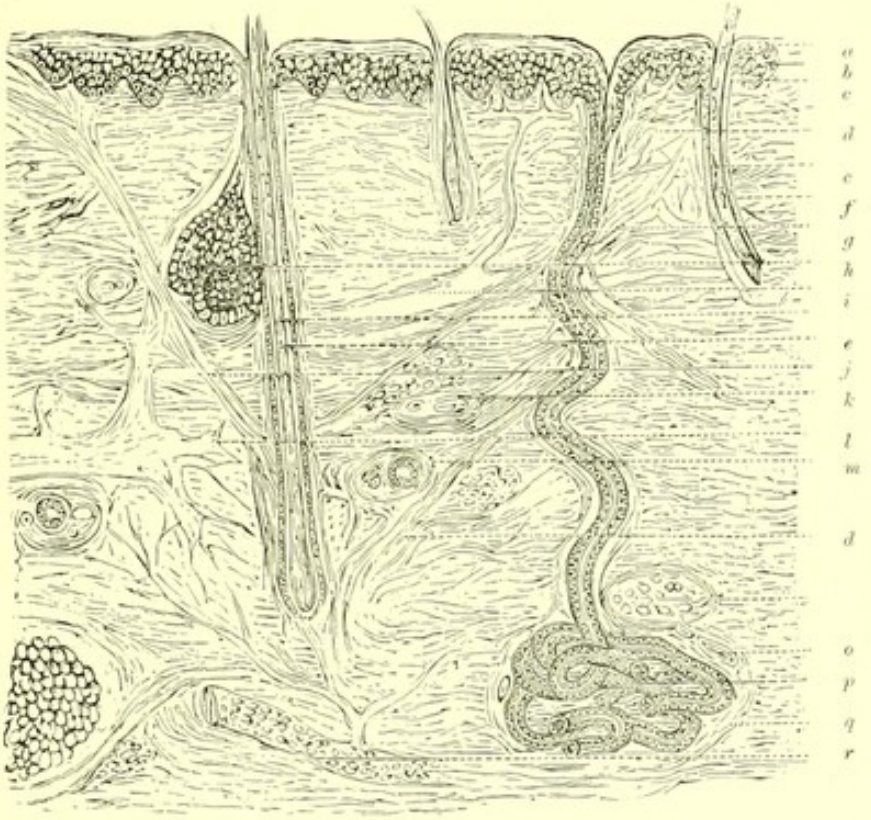


FIG. 21.—A VERTICAL SECTION OF HEALTHY SKIN × 60.
(Sketched from three preparations, with a camera lucida.)

a, Horny, and *b*, Mucous layer (*Rete Malpighii*) of the Epidermis; *c*, Papillary layer of Corium (*d*, *d*); *e*, Hair; *f*, Hair follicle; *g*, Duct of sweat gland (*p*); *h*, Sebaceous gland; *i*, Blood-vessel sending up branches to papillæ (*c*); *j*, Arrector pili; *k*, Section of vessels with their surrounding *adventitia*; *l*, Delicate fibrous tissues continuous with adventitia of blood-vessels and lymphatics; *m*, Section of sudoriparous duct and blood-vessels; *n*, Areolar tissue and fat cells; *o*, Section of vessels within the capsule (*q*) of the convoluted portion of sweat gland (*p*); *r*, Blood-vessel filled with corpuscles, giving off a twig to the root of the hair.

portion of these cells cannot be represented in a drawing made on so small a scale as this), but also forms a coating to the projections of the true skin or *cutis vera* (*d*) termed papillæ (*c*). Into the latter nutritive vessels (*i*) and nerves penetrate. The epidermic layer—the mucous portion of it especially—not only dips between the papillæ for the purpose of supplying them with a covering, but also dips still more deeply into the tissue of the true skin, and thus aids in forming to a greater or less degree the walls of all the tubular structures which open on the surface of the body. These are hair- (*f*) and sebaceous follicles (*h*), and the ducts of the sweat glands (*g*).

These structures, divided, however, transversely or obliquely, may be distinguished in almost any section of the skin that may be examined, as well as the connective and elastic tissue and the aggregations of fat cells in the areolar tissue below, which go

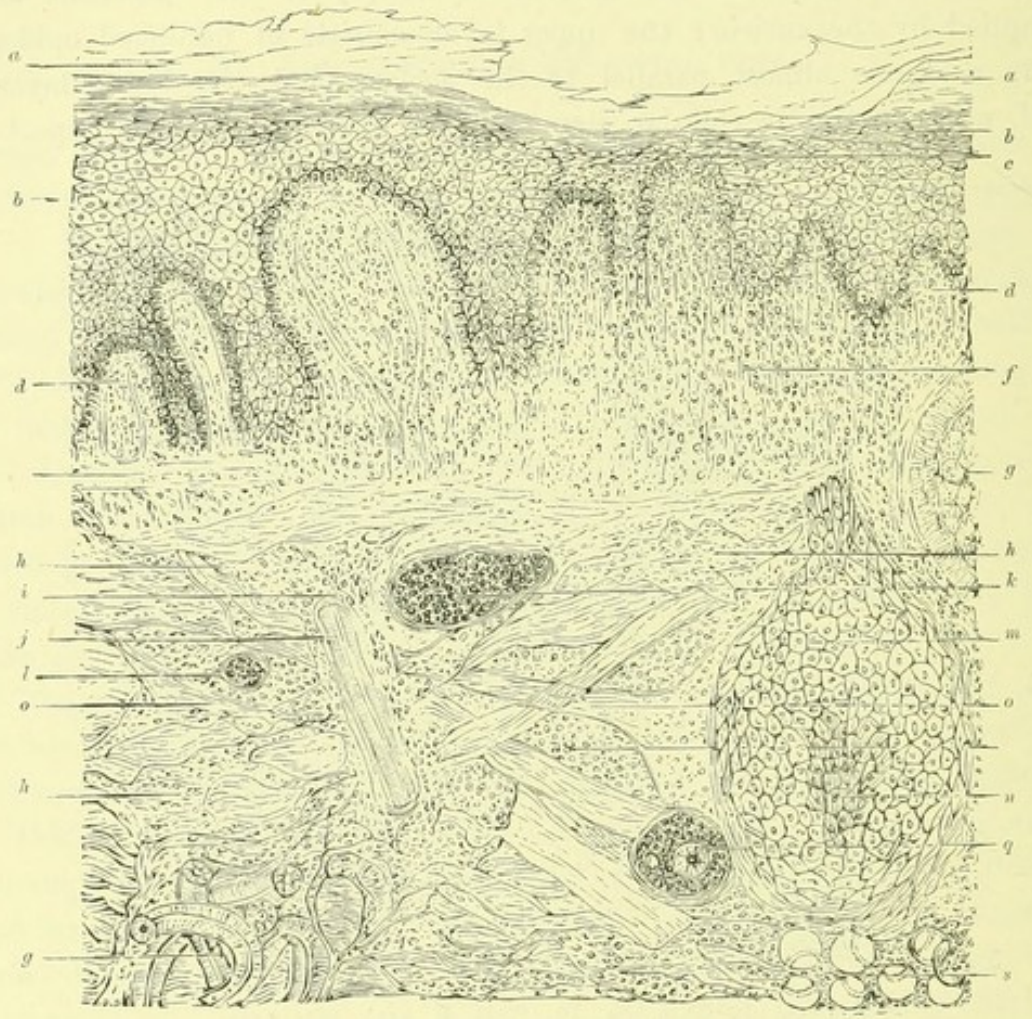


FIG. 22.—VERTICAL SECTION OF A "DELHI SORE" × 60.

(Sketched from three preparations, with the aid of a camera lucida.)

a, *a*.—Horny layer of epidermis coated with a thin encrustation. *b*, *b*—Mucous layer of epidermis (*Rete Malpighii*) thickened, and the epithelial cells enlarged. *c*.—Commencement of rupture of epidermic layers, and walls of papillæ (*d*, *d*). *e*.—Vessels proceeding to papillæ. *f*.—The new growth composed of lymphoid cells, which at *h*, *h*, *h* is seen in intimate relation with delicate threads of fibrous tissue (the *adventitia* of the vascular and glandular structures?). *g*.—Partially disintegrated sebaceous follicle. *i*.—Line of section of tissues surrounding a sweat duct (*j*), prolongations of which (*h*) are seen studded with the lymphoid corpuscles. *k*.—A space filled with lymphoid corpuscles (a "colony"). *l*.—Section of blood-vessel surrounded by an aggregation of lymphoid corpuscles. *m*.—Disorganised hair follicle showing the remains of a hair within the sac (*n*). *o*, *o*.—Decussating bands of connective tissue giving rise to interspaces (*p*), which are packed with lymphoid cells. *q*.—Section of sudoriparous duct surrounded by lymphoid cells; a blood-vessel is also visible within the general sheath. *r*.—Convoluted part of a sudoriparous gland. *s*.—Fat cells with corpuscular elements among their investing areolar tissue.

to form the greater portion of the true skin. Scattered in the meshes of these fibrillated tissues the above-mentioned glandular and other structures are found, together with numerous vascular textures, sanguineous and lymphatic.

A very cursory glance at the illustration of a section of similar structures as

modified by the morbid process associated with Delhi sore will suffice to indicate in a general way the principal alterations which the tissues have undergone. The horny layer of the cuticle (Fig. 22, *a*) is found to have become thickened, except at the site of actual breach of continuity, and the mucous layer (*b*) has become much more pronounced in its character, not only by increased thickness, but also by its more cellular character. The epithelial cells have become distended and their nucleus more distinct, and the epithelial character of the inter-papillary processes is much more distinctly marked than is the case in sections of normal tissue. The prickly appearance of a large portion of the epithelial cells is well marked.

The papillæ likewise are enlarged in all directions, and frequently their contained capillaries are found much congested, rows of tightly packed red corpuscles being frequently distinguishable along the entire length of a papilla.

The most marked alteration, however, which the papillæ manifest is due to the number of lymphoid corpuscles which occupy every available crevice between their vascular and other tissues; but, except in case of actual rupture, as at *c*, these corpuscular elements do not extend beyond the epithelial boundary of the papilla. It is seldom that a lymphoid corpuscle can be observed entangled in the midst of the cells forming the Malpighian layer, whose presence there cannot pretty clearly be attributed to accidental causes in connection with the preparation of the specimen.

On examining a vertical section of a hardened specimen of the sore under a low power, by the aid of reflected light, striæ of these corpuscular elements may be observed descending through the corium in a direction towards the base of the tumour and continuous with the lumen of the papillæ. When thus examined, the striæ present a whitish, pearly aspect. These striæ manifestly correspond to the pinkish striæ which we have just described as being conspicuous in perfectly fresh preparations, owing to the congested condition of the blood-vessels along which the lymphoid corpuscles are in great part distributed. The colouring matter, however, of the red blood cells gradually disappears in course of preservation.

The spaces between the striæ are occupied in the upper part of the section by prolongations formed of epithelial cells continuous with the rete Malpighii, which gradually assume a more spindle-cell aspect the further they are removed from the ordinary level of the mucous layer, and in the lower part by connective tissue. Where, however, the striæ become less evident, and when the bands of connective tissue in the corium are seen to decussate in a more marked manner (Fig. 22, *p*), the pearly striæ disappear and isolated aggregations of similar aspect may be seen between the meshes of the fibrous tissue. The application of a higher magnifying power shows that the corpuscular elements forming these pearly (when examined by reflected light) areas consist of lymphoid cells identical with those which occupy the papillæ, and which are what may be considered as the strictly new growth in Delhi sore.

Various other changes are manifested in a preparation of the sore, which,

however, may be ascribed more manifestly to modifications of pre-existing structures —modifications, too, which presumably are the indirect results of the development of the corpuscular elements which have just been referred to. These changes are most pronounced in the case of the hair and the sebaceous follicles (Fig. 22, *m. g*). The hair itself disappears more or less completely, at most leaving but very trifling traces in the form of a few hardened scales (*n*), or perhaps merely a small heap of molecular *débris*. As already mentioned, the altered follicles become pushed forward by the new growth until, eventually, in advanced cases they are found lying free on the surface of the sore (Figs. 16, 17).

The sebaceous follicles also suffer in like manner (Fig. 22, *g*); indeed, it is very seldom that they can be identified as glandular structures at all when the particular sore examined is not a very recent one. There does not appear to be any infiltration of lymphoid corpuscles into either the hair or the sebaceous follicles; the changes in both consist, for the most part, apparently, in an increase in the size and the more pronounced character of the epithelial cells which enter into their formation, just as was observed to take place in the mucous layer of the epidermis. With reference to the sebaceous follicles, however, we were not able to satisfy ourselves that more changes than this had not taken place, as some of them appeared to be filled with material consisting of broken-down epithelial elements, or with indistinctly marked lymphoid corpuscles. We are, however, inclined to refer it to the former. The fibrous tissue forming the capsular investment of both classes of follicles were frequently infiltrated with accumulations of lymphoid cells.

The sweat glands, situated in the lower part of the corium (Fig. 21, *p*, Fig. 22, *r*), are not appreciably affected unless the sore is in a very advanced state. Frequently the glandular convolutions may be seen to present an almost perfectly normal appearance (Fig. 22, *r*), even when surrounded by the lymphoid corpuscles. The ducts, however, are generally larger than usual, and sometimes they are seen to have become obliterated, apparently as the result of the pressure exercised by the newly-formed cells of the sore. Occasionally, however, the appearance presented by the cellular lining of the ducts and its convolutions seemed to indicate that, as in the case of the sebaceous glands, some change had occurred, but whether neoplastic or retrograde we were unable to decide.

It is in connection with the vascular structures of the corium that the essential features of the disease are most prominently observed. This, however, does not imply that the primary deposit takes place in the interior of the vessels, or even in the interior of the capillaries; for very frequently sections of the blood-vessels parallel to their course may be encountered, which prove that they contain no corpuscular elements other than those normal to them, although it is frequently to be noted that they are very full. The same is observable in transverse sections. The coats of the vessels are, however, generally thickened and somewhat more readily resolved into their cellular elements than is the case in normal tissues.

In endeavouring to trace a connection between the lymphoid cells and the various tissues of the corium, all preparations demonstrate more or less clearly that the distribution of these elements is more intimately connected with the delicate fibrous tissue-investment of the glandular and vascular structures than with any other tissue. In following the course of a blood-vessel, for example, it will be observed that aggregations—colonies of lymphoid cells—have formed in numerous places, and that from these "colonies" ragged processes of delicate fibrous tissue may be recognised which become joined to similar processes in other parts of the preparation (Fig. 22, *h,h,h*). In other instances these delicate fibrous shreds may be seen to be directly continuous with the *adventitia* of a vessel, and to become more and more distinctly dotted with lymphoid cells until they are lost in a sheet, so to speak, of similar fibrous tissue at a distant part of the preparation. Similar accumulations of these granular corpuscles may also be found surrounding the blood-vessels when the latter are cut transversely (Fig. 22, *l*), as also surrounding the convolutions of the sweat glands in connection, probably, with the *adventitia* of their vascular tissues.

The circumstance that the lymphatic vessels may sometimes be seen in the corium to take a course some distance removed from the blood-vessels enables us also to observe that in very early stages of the disease the lymphoid cells, of which we have been speaking, are in more manifest relation to the connective tissue along the course of the lymphatics than elsewhere; but we have not been able to satisfy ourselves that the cells are found within the larger lymphatic vessels; on the contrary, not unfrequently they form larger aggregations in the fibrous tissue which is seen to proceed from such a vessel and at some distance from it.

In addition to these aggregations or colonies of lymphoid cells which surround the sweat glands, the hair and sebaceous follicles, and the different vascular tissues with distinct walls, aggregations may frequently be observed without perceptible connection with any of these structures (Fig. 22, *k*). It is possible that these colonies may be due to the accumulation of the cells in the interstices formed by decussating fibrous bands, or to their accumulation in the spaces of the *adventitia*.* Possibly both conjectures are correct, seeing that the outline of the colony frequently corresponds to the margins of the spaces formed by the decussating fibres, and that when no such bands are present to modify the shape of the colonies, they are usually round or oval. The average dimensions of ten of the colonies which we measured was $\frac{1}{100}''$ (=0·25 mm.), but they varied from $\frac{1}{166}''$ (= 0·15 mm.) to $\frac{1}{42}''$ (= 0·4 mm.).

Sometimes, as already mentioned in describing the microscopic appearances of an extirpated sore (page 425), its base is dotted with minute projections about the size of the head of a pin, which become more evident after the preparation has been dried or hardened in spirit. These little prominences are found to consist in some cases of the

* We have refrained from giving any name to these spaces so as to avoid the possibility of misconstruction, seeing that different writers make use of the same designations for very different structures in accordance with the particular view adopted.

convoluted portion of sweat glands surrounded by aggregations of lymphoid cells; in other cases no trace of a sweat gland is to be observed, but an oval or circular colony of cells, surrounded by a scarcely perceptible membranous envelope, and showing towards its centre the cut orifice of a blood-vessel, are all that can be distinguished.

There remains one other feature in connection with this cell-growth which deserves special mention; and that is the fact that the reticulated tissue in which the fat cells are embedded is frequently thickly studded with these lymphoid cells (Fig. 22, *s*)—a fact, however, which generally requires the use of re-agents, such as iodine, picro-carmine, or aniline, for its elucidation.

Having thus briefly described the general features of this cell-growth as seen in vertical and transverse sections of extirpated sores, it will be necessary to describe the arrangement which the cells assume with regard to each other.

It should be premised that the cells as well as the substance in which they are embedded assume very different appearances according to the particular method adopted for their preservation and the different staining processes resorted to. The description which follows will refer to preparations which have been preserved in spirit, in a weak solution of chromic acid, and in a mixture of the two.* With regard to the size of the corpuscles when measured after preservation in spirit, it may be stated that the average of ten measurements of cells taken indiscriminately was $\frac{1}{3500}''$ (=·0048 mm.), —the extremes being $\frac{1}{4666}''$ (=·0036 mm.) and $\frac{1}{2333}''$ (=·0072 mm.).

In order to study the minute structure and relations of these corpuscular elements, it is essential that the sections should be made as thin as possible. Our sections were for the most part made from hardened preparations which had been embedded in paraffine and sliced by means of a broad and very sharp razor. The margins of almost any such preparation obtained in this manner will suffice to demonstrate the appearance presented in the accompanying woodcut (*vide* Fig. 23). The cells are observed to be of various shapes and sizes; some are spindle-shaped, with a well-marked oval nucleus, others appear to be intermediate between spindle cells and epithelial cells on the one hand, and lymphoid cells on the other, but the bulk of the cells consists of the granular lymphoid kind. As, however, the relation of these varied cells to each other constitutes one of the leading questions under discussion in modern biological research, it would be presumptuous to attempt to offer any opinion on the matter at present, especially in connection with a subject which has not been investigated for the purpose of attempting to solve so difficult a problem. It is sufficient for our purpose to know—

1. That the morbid growth consists of granular lymphoid cells measuring from $\frac{1}{4000}$ (=·006 mm.) to $\frac{1}{3000}$ (=·008 mm.) of an inch in diameter, in which, without the addition of acetic acid, one or more nuclei may generally be detected.

* It may be mentioned in connection with the preservation of specimens, that tissues which have been preserved in solutions of chromate of potash or chromic acid are very apt to become the sites of growth of fungi. One of the specimens of *healthy* skin which we preserved in chromic acid during our stay at Delhi was a few weeks subsequently found to be covered with a thick layer of mould as well as the fluid itself, which, having partially evaporated, had allowed the fragment of skin to project somewhat beyond the surface.

2. That these cells are embedded in a cement-substance not readily detected in fresh preparations, but becoming firmer and less translucent by the action of spirit and other preservative media.

3. That, as in ordinary adenoid tissue, the corpuscular bodies may be brushed out of the meshes of the substance in which they are embedded.

4. That the cells are frequently observed to be arranged linearly, four or five corpuscles being placed in a row with, very frequently, a delicate string of fibrous tissue on either side.

5. That the corpuscles vary in appearance from mere irregular lumps of plasma to well-formed lymphoid cells, in such intimate relation with which, as almost to be

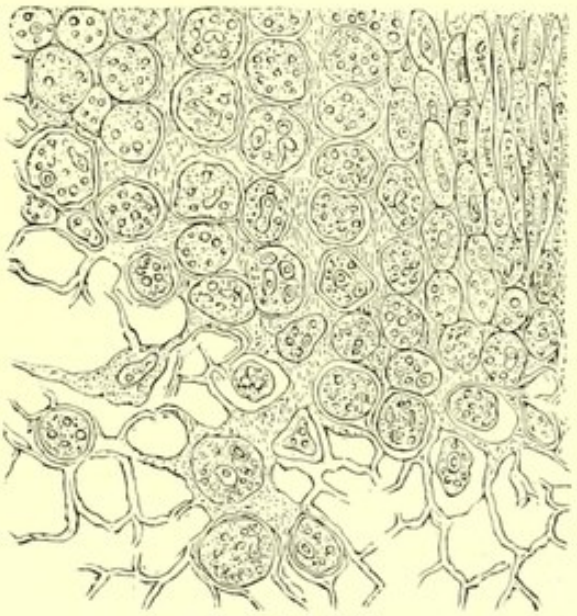


Fig. 23.—Section of a portion of a "Delhi Sore" which had been preserved in spirit and weak chromic acid— × 850 (Hartnack's Obj. No. 9 immersion).

suggestive of organic connection, are spindle-shaped and epidermoid cells in various grades of transition.

6. That the lymphoid corpuscles are found in intimate relation with the *adventitia* of the vascular tissues, notably those of the lymphatics of the corium, and that they tend to become aggregated into "colonies" of various size.

7. And finally, that the cells becoming pushed forward by the subjacent growth of others, gradually find their way to the surface through rents in the papillæ (*vide* Fig. 22).

Such are the salient points which we have been able to observe in connection with the minute anatomy of the Delhi form of the Oriental sore.*

* During our stay at Delhi we made several attempts to transfer the disease to dogs by means of inoculations of perfectly fresh material derived both from the surface and substance of typical examples of the complaint; and made counter experiments by irritating small surfaces of healthy skin with acid and with iodine. The results were not such as to call for any detailed account. We found that the irritated surfaces, no matter how induced, ran a somewhat similar course—the purely chemical irritants being to all appearances as deleterious as the matter obtained from the sore. The microscopical elements of which these artificially induced little ulcers consisted were identical.

CHAPTER VI.

REGARDING THE PROBABLE NATURE OF THE ORIENTAL SORE AND ITS RELATION TO RECOGNISED SKIN AFFECTIONS IN EUROPE.

We trust that our descriptions of the clinical and pathological features of this sore suffice to decide as to the propriety of identifying it with a form of a cutaneous affection which exists in Europe, and of classing it among the recognised skin diseases. For our own part we have little doubt that were a person suffering from such an affection to present himself at any of our English or Continental hospitals without divulging an Oriental history, there would be no great hesitation on the part of the physician in diagnosing the case before him. Given, for example, a case in which a sore is found on the cheek, another on the forehead or back of the hand, with perhaps a scar or two elsewhere, the cicatrices of former sores. Assume that one or more of these are surrounded by a somewhat hardened, slightly elevated, glossy margin; that they are nearly painless, have been very gradually, almost imperceptibly, spreading for weeks or months, although the general health of the patient does not appear to have been materially affected, and that no history of syphilis or scrofula can be ascertained. Putting these leading points together, the physician would in all probability pronounce it a case of one or other of the generally recognised forms of *Lupus*.

When, in addition to the clinical history and microscopical appearance of the affection, the microscopical features of the sore, as given in the last chapter, are carefully considered, the evidence in favour of the correctness of such a diagnosis is almost beyond question. The pathological changes which we found to have occurred in the corium and in the rete mucosum correspond very accurately with what Virchow has described as characteristic of Lupus in his classical work on "Diseased Tumours."* Had Professor Virchow's description been published as one referring to specimens of the Oriental sore as seen at Delhi, we would unhesitatingly have added our testimony to its surprising correctness. His description of epidermal changes, of the changes in the hair and sebaceous follicles in Lupus find their counterpart in our own description of this sore, and we are particularly struck with the similarity which exists between his description of the epidermoid character of some of the portions of diseased tissue in Lupus and what we have seen in the Oriental sore, and that, too, at a considerable distance from the epithelial layers.

Professor Virchow writes: "The Lupus growth consists of young, tough, and generally, vascular, granulating tissue, which as a rule contains small round cells, which may so closely resemble the cells of the rete Malpighii, that it is difficult to differentiate the boundaries between the rete and the Lupus tissue. Frequently it seems as though the boundary had been obliterated, but I cannot admit, what might readily be supposed, that the cutis itself becomes transformed into a rete Malpighii, or that the

* "Die Krankhaften Geschwülste,"—Band II. S. 485, et seq.

elements of the rete press into the cutis. A decidedly epidermoid character is not assumed by the cells: they are young cells, of irregular form and of moderate durability. . . The cells do not lie loose in the areolæ, but are surrounded by tough, mucous intercellular substance giving a precipitate with acetic acid. The cells are delicate and fragile, and one may readily infer that they are only nuclei. . . . A careful examination, however, will reveal that they are cell bodies, generally rounded, but often oval or even spindle-shaped. They envelope the round or oval, large and generally single nucleus tolerably closely, and the latter is provided with one or two nucleoli. It is only towards the surface that the cells become multi-nucleated, occasionally presenting precisely the appearance of pus corpuscles." *

Subsequent to the period at which this description was written several distinguished observers have paid special attention to the pathology of Lupus, and notably so during the present and past year. Thoma also directs attention to the gradual extinction of the boundary line between the corium and rete Malpighii—such an extinction as may be observed delineated in our figure of a section of the Oriental sore (Fig. 22, *c*); and lays stress on the point that the cell formations which take place in the corium are the essentially Lupus elements. At first, he says, cell-growths occur in the perivascular spaces of the blood-vessels of the skin,† aggregations of lymphoid elements which gradually penetrate all the interfascicular spaces of the corium, separating the connective tissue filaments normal to the corium.‡

Still more recently Lange has published a carefully written paper on the "Histology of Lupus," accompanied by figures which might almost have served as illustrations to many of our own preparations of the "Delhi sore."

We might go on citing authorities concerning this matter almost indefinitely, but as it is not our intention to discuss the various doctrines maintained regarding the particular tissues primarily involved in the affection, or to express any opinion on purely histological points, enough has been written to show that the microscopical changes which characterise the "sores" ordinarily met with at Delhi, and which are considered endemic to this and other localities, differ in no material manner from the changes which have been described as taking place in the various forms of Lupus in Europe. To those who desire a lucid *resumé* of the various doctrines advocated in connection with the pathology of Lupus, we would recommend the perusal of the chapter on the subject in the last edition of Neumann's work on "Skin Diseases." §

Although none of the various pathological changes which have been described in connection with Lupus, and which we now refer to in relation with the Oriental sore when taken singly, can be designated as peculiar to either the one or the other, seeing that similar changes, though possibly differing in degree, are known to occur

* Op. cit., pages 487-8.

† This view is in accordance with the researches of Dr. Thin regarding the origin of Lupus Erythematosus: *Lancet*, January 16th, 1875.

‡ Virchow's *Archiv*. Band. LXV; Heft. 3; *S.* 335—1875.

§ "Lehrbuch der Hautkrankheiten," von Isodor Neumann; vierte Auflage—Wien 1876.

in other cutaneous affections, still, taking the appearances in the aggregate, they are sufficiently characteristic, more especially when, in addition, the clinical features of Lupus and of the Oriental sore are considered and compared. There can then be little doubt but that the diseases correspond in all the main points, and may be looked upon as essentially the same.

Whilst this paper was in course of preparation, we had the opportunity of perusing a very carefully written account by Dr. Geber of a sojourn in Aleppo for the purpose of investigating the nature of the affection known as the "Aleppo Bouton."* The sores referred to under this designation are, as already intimated, considered by all authorities to be, in all essential points, the same as those encountered in other parts along the Mediterranean, in Egypt, Arabia, India, and other Eastern countries. Dr. Geber has come to the conclusion that several kinds of affections are designated by the same term in Aleppo, but that all of them may be readily identified by any experienced dermatologist. For the most part, he looks upon the sores which prevail as more or less typical of Lupus; but a considerable number of the "boutons" investigated proved to be of syphilitic or scrofulous origin.

These observations are in complete accord with our own experience in Delhi, with the exception that we did not observe any instance in which cases had been diagnosed as Delhi sores, by a qualified observer, which had any history to indicate that they were due to syphilis or scrofula. Errors of diagnosis, doubtless, occur in the bazaars and among the population generally, but the cases which medical practitioners recognise as Delhi sores are, we believe, for the most part cases of one or other of the varieties of Lupus.

It is, however, highly probable that, owing to climatic and other differences, the disease may be modified in some degree from its European prototype; we know that it differs from it in being more localised to certain districts; in this, however, it is not altogether peculiar, for there are some other diseases which manifest distinctly endemic proclivities in this country without any such proclivities being recognised in England. Dr. Geber cites an instance of a school in Aleppo in which he identified 24 cases of Lupus (in addition to other skin affections) among 130 children, all of which were recognised there as "boutons." It would be hardly possible to find a school with such a proportion of sores in England, or to meet with such a number of persons in the streets marked with sores or their cicatrices as may be met with in Delhi. It seems, then, but natural to infer, that although the character of the sores present so much in common with Lupus as seen in Europe, some peculiar conditions exist in the locality which are sufficient not only to induce or predispose to the disease, but also possibly, in some respects, to modify its character, so that it would be well for purposes of classification to give it a specific designation. We would propose, therefore, that *Lupus endemicus* might be adopted as a sufficiently explicit definition of its nature and habitat.

* "Erfahrungen aus meiner Orientreise." *Vierteljahreschrift für Dermatologie.* Heft 4. Wien 1875.

SUMMARY.

THE report which we now bring to a conclusion may be thus briefly summarised:

1. Assuming that the cutaneous affection which we have studied at Delhi is, practically, of the same nature as the sore which is prevalent in Mooltan, Lucknow, Lahore, Scinde and other parts of India, as also the chronic sore known in Aleppo, Biskra, Bagdad, etc., as "bouton," it comes under the general designation suggested by Dr. Tilbury Fox of "Oriental sore":
2. Our information of the distribution of the sore in India is taken from the statistics regarding "abscess and ulcer" collected from all parts of the country, but our pathological observations are, for the most part, based on typical examples of the affection witnessed at Delhi:
3. Whereas of late years the statistical returns indicate considerable diminution in the number of hospital admissions among European troops from "abscess and ulcer," and among native troops also in such stations as are garrisoned by the two classes of soldiers; there is no such manifest decrease in the stations occupied solely by sepoys:
4. This discrepancy may be due to more attention having been paid to the sanitary requirements of those stations at which European troops are located:
5. That although at Delhi this inference does not constantly hold strictly correct, nevertheless it appears to do so at those seasons when the European and native soldiers are placed under equally advantageous conditions as to water:
6. In those years, when sores were notoriously prevalent among both the European and native troops stationed in Delhi, their water-supply was derived from wells. Latterly, the European troops in the Fort have been supplied with water from the river Jumna, whereas the native troops still resort to the wells. The wells, however, are flooded with water from the canal, which is derived from the Jumna, some miles distant. The canal supply occasionally fails, the well water assumes the character normal to the locality, and cutaneous disorders are a not uncommon sequence:
7. So far as our own observations go, there is no evidence of any parasitic agency in the production of the disease, and it appears probable that the deleterious effects are due to the chemical constituents of the water. In Delhi the quantity of salts with which the water is impregnated and its extreme hardness in so many of the wells is the most noteworthy feature. The unoxidised organic contents of the water would not appear to be of material influence, seeing that the water is not worse or even so bad as in many of the stations in Lower Bengal, where this cutaneous affection is, practically, unknown:
8. Although we are not in a position to speak definitely regarding the character of the wells in other military stations where the Oriental sore prevails,

owing to the lack of analyses of assured accuracy, yet appears highly probable, judging from the geographical position of the stations and from the statements of residents of several of them, that the well waters manifest properties similar to those which they possess in Delhi. The well waters in many of the places where the sore prevails, in Egypt, Asia Minor, Syria and other countries, are also notoriously more or less brackish:

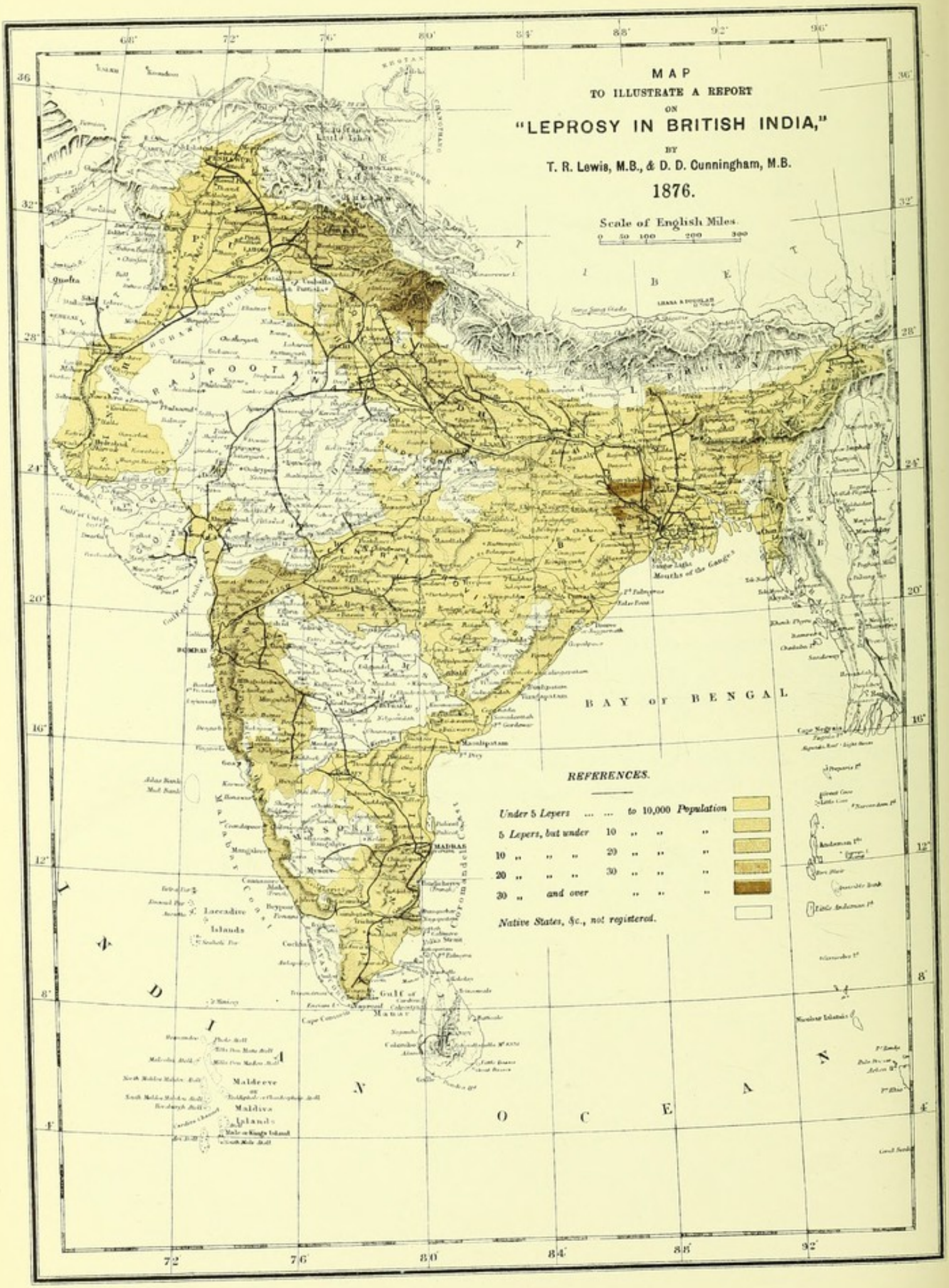
9. It seems, therefore, probable that although the salts, which cause the hardness of a water, may of themselves not be the actually deleterious ingredients, nevertheless this quality may serve as an index of properties in it which tend to favour the production of cutaneous disorders. Several salts exert a peculiar action on the skin; those of Iodine and Bromine, for example, produce very characteristic eruptions:

10. With regard to the special skin affection in question, we have no hesitation in suggesting that the disease, as commonly observed at Delhi, setting aside all cases which are manifestly due to syphilis, scrofula and the like, is in no way distinguishable from one or other of the various forms of Lupus; its clinical history is similar, as is also its morbid anatomy; and the treatment which has proved the most satisfactory is that which is generally recommended for Lupus:

11. It is probable, however, that, owing to climatic and other influences it may be somewhat modified from its European prototype as suggested by the fact of its prevalence being limited to particular districts—a feature which, so far as we are aware, does not characterise it in Europe in any special manner; and

12. Finally, we have suggested that the tendency which this form manifests to become endemic may be taken advantage of for purposes of nomenclature, and have therefore proposed that this form of Oriental sore should receive the designation *Lupus endemicus*.

CALCUTTA,
November 1876.


MAP
TO ILLUSTRATE A REPORT
ON
"LEPROSY IN BRITISH INDIA,"
BY
T. R. Lewis, M.B., & D. D. Cunningham, M.B.
1876.
Scale of English Miles.
0 50 100 200 300
REFERENCES.
Under 5 Lepers ... ... to 10,000 Population
5 Lepers, but under 10 " " "
10 " " " 20 " " "
20 " " " 30 " " "
30 " and over " " "
Native States, &c., not registered.
BAY OF BENGAL
INDIAN OCEAN
Laccadive Islands
Maldive Islands
Gulf of Manar
Mouths of the Ganges
BOMBAY
MADRAS
Quetta
Cape Comorin
Cape Negrais
Andaman I.
Nicobar Islands
Coromandel Coast
Malabar Coast

LEPROSY IN INDIA.*

BY

T. R. LEWIS, M.B., AND D. D. CUNNINGHAM, M.B.

INTRODUCTION:—THE DISTRIBUTION OF LEPROSY IN BRITISH INDIA.

IT is only within the last few months that it has become possible to obtain definite information regarding the local distribution and comparative prevalence of leprosy in the different districts of India. Now, however, that the Census Reports of 1872 have been issued, persons interested in the subject are in a position to form as correct an opinion regarding, not only the aggregate number of lepers, but also the distribution of the infirmity in India, as they are, probably, in almost any other country where leprosy prevails. In such a mass of figures it is doubtless probable that many errors have crept in, and that many persons have been registered as lepers who were not affected with true leprosy—notably such as are subject to that peculiar cutaneous affection characterised by more or less complete loss of pigment (*Leucoderma*). On the other hand, however, this excess may be balanced by the fact that quite as many, if not more, have been left out altogether.

It is evident regarding the latter possibility, that as lepers formed one of the five classes of "infirmities" which were registered all over British India—the others being "Insanes," "Idiots," the "Deaf and Dumb," and the "Blind"—persons may have suffered from leprosy for years without having been looked upon as lepers by the community, much less considered "infirm." The registration of some of the other "infirmities," such as dumbness and blindness, is not so liable to be affected by this manner of classification, although, even as regards such an infirmity as blindness, persons were not unfrequently returned in this category owing to their being possessed of but one eye. The want of more accurate definition was, probably, chiefly owing to the difficulty experienced in dealing with the different languages and dialects over such vast territories; in not a few cases, indeed, the expressions for some of the infirmities were found to have different significations in different parts of the same district.

* Appeared as an Appendix to the *Twelfth Annual Report of the Sanitary Commissioner with the Government of India*, 1876.

Notwithstanding all this, however, the statistics are sufficiently exact with regard to such questions as the geographical prevalence of leprosy in this country to be of the utmost value, both to those who are engaged in the study of its causation, and to those who have been anxiously endeavouring to devise means for dealing with it in a practical manner.

We have gone over these figures very carefully, and have endeavoured to extract from them what appeared to us their most important features; we have also attempted to bring the returns of the different Presidencies and Provinces into such relation as to be fairly comparable. In some of the cases we have found considerable difficulty in doing so, owing to the great disproportion in the population of the areas which form the divisions, collectorates, and districts in the three Presidencies; for example, the population of a single division in Bengal—that of Burdwan—is equal to nearly half the population of the whole Presidency of Bombay. These we have attempted to correct as far as possible, and trust that a sufficiently succinct Tabular Statement of the distribution of the disease over British India has been devised to enable those interested in the question to estimate with a fair amount of accuracy the degree of its severity and the particular parts of the country specially affected.

In order still further to simplify this question, we have compiled a map of the disease as it is distributed over the country, which represents, graphically, the Tabular Statements gathered from the different censuses. The map has been very carefully compiled, and may be looked upon as representing in a fairly accurate manner the distribution of the disease in accordance with the most recent official returns. Every district in the country was separately picked out on maps drawn on a large scale and tinted in accordance with the ratios found in the various columns in the original Census Reports, and the sheets were subsequently reduced to more portable dimensions. We have to acknowledge the great assistance which we obtained from Captain Waterhouse, Assistant Surveyor-General of India, in carrying out this scheme.

A glance at this map shows that there are three districts—large tracts of the country—where leprosy prevails to an extraordinary extent: namely, Beerbhoom and Bancoorah, in the Burdwan division of Lower Bengal; the Kumaon division of the North-Western Provinces, extending across the southern range of the Himalayas; and the Deccan and Konkan divisions of the Bombay Presidency. The latter area, considered as a whole, does not show such an extreme prevalence as the two others: leprosy is, however, extremely prevalent, and in some districts, such as Barsi, Sowda, and Rajapur, abounds to a degree as great as is manifested in Beerbhoom, Bancoorah, and Kumaon.

Total Number of Lepers in the Three Presidencies.

The accompanying summarised Tabular Statement shows that there are more than 99,000 leprous persons in British India alone, or at the rate of 54 cases in every 100,000 of the population:—

TABLE I.

Showing the Number of Leprous Persons, and the Proportion in the Three Presidencies, together with the Total Population on which the Ratios have been calculated.

	Total Population on which the Leper-ratios have been calculated.	Total Lepers.	Proportion of Lepers in every 10,000 [Ten Thousand] of the Population.
Bengal Presidency	135,456,138	71,287	5·2
Madras „	31,152,272	13,944	4·4
Bombay „	16,228,774	13,842	8·5
GRAND TOTAL IN BRITISH INDIA ...	182,837,184	99,073	5·4

Of the three Presidencies, Madras, though not containing the fewest lepers, taking the absolute numbers, presents the lowest ratio, *viz.*, 44 to 100,000; whereas Bombay presents a proportion of leprous population nearly double that of Madras—85 lepers to every 100,000, although the absolute number of lepers in the Bombay Presidency is slightly fewer. The Presidency of Bengal furnishes an intermediate proportion—very considerably lower, however, when the whole Presidency is considered, than that of Bombay. The figures in the following table, however, point to the fact that one of the divisions in Bengal (Burdwan) contains a greater proportion of lepers, and absolute numbers almost as great as those of the whole of the Bombay or Madras Presidency.

In Table II. (on the following pages) will be seen the figures giving the total numbers of lepers recorded in the Census Returns of this country, but on the present occasion it will be sufficient to refer to them collectively, for the most part, as it will be more convenient to examine them categorically on a future occasion.

With regard to the portions of the Table that refer to the Punjab, Oudh, and the Berars, it is to be remarked that the statistical details are not so fully given as in other parts of the country, so that we have been compelled to resort to such official documents as we could procure other than the local Census Reports. In arranging the Leper Returns for the Punjab, for instance, we have made use of some valuable data which its Sanitary Commissioner, Dr. D'Renzy, had collected; and the figures regarding leprosy in the Berars were obtained from the Oudh Census Report, published in 1869. Unfortunately when the census of Oudh itself was taken, the leper population was ascertained in only one district, Hurdui, so that merely an estimate of the aggregate number can be submitted. During the present year, however, another district has been registered, that of Unao, and this gives a proportionate result precisely corresponding with that registered on a former occasion.

With these exceptions, the figures in the Table have been derived from the original census records as published by various local Governments.*

* In some of the Census Reports the nearest whole numbers have been given instead of the decimal fraction.

TABLE II.

Showing the Distribution of Leprosy in British India.

	Divisions.	Total number of Lepers.	Proportion of Lepers in every 10,000 [ten thousand] of the population.
	BENGAL.		
Bengal Proper.	Burdwan	12,081	16·5
	Presidency	3,682	5·6
	Rajshahye	6,182	6·9
	Cooch Behar	244	5·7
	Dacca	5,299	5·5
	Chittagong	915	2·6
	Total	28,403	7·8
Behar.	Patna	5,742	4·3
	Bhaugulpore	2,031	3·0
	Total	7,773	3·9
Orissa	Orissa	1,077	2·4
Chota Nagpore.	Chota Nagpore	567	2·6
Assam.	Assam	309	1·6
	Grand Total in Province	38,129	5·4
	NORTH-WESTERN PROVINCES.		
	Meerut	1,463	2·9
	Rohilcund	2,256	4·2
	Agra	1,145	2·3
	Jhansie	211	2·3
	Allahabad	1,828	3·3
	Benares	1,625	2·0
	Kumaon [with Garhwal]...	1,571	21·0
	Total	10,099	3·3

	Divisions.	Total number of Lepers.	Proportion of Lepers in every 10,000 [ten thousand] of the Population.
	OUDH.		
	Lucknow [Unao District in]	650	7·0
	Rae Bareli...	?	
	Fyzabad	?	
	Seetapur [Hurdui District in]	688	7·0
	Estimated Total ...	7,831	7·0
	BERARS.		
	Berars	1,432	6·0
	CENTRAL PROVINCES.		
	Nagpur	892	4·0
	Jubbulpore	137	1·0
	Narbada	552	3·0
	Chattisgarh	1,216	4·0
	Upper Godavari	10	1·0
	Total	2,807	3·0
	PUNJAB.		
	Delhi	1,273	6·6
	Hissar	605	4·9
	Umballa	1,524	9·2
	Jullundur	2,758	11·1
	Amritsar	1,774	6·4
	Lahore	633	3·3
	Rawalpindi	1,613	7·3
	Mooltan	452	3·0
	Derajat	153	1·5
	Peshawar	204	1·9
	Total	10,989	6·2
	Grand Total in Bengal Presidency	71,287	5·2

TABLE II. (*continued.*)

Showing the Distribution of Leprosy in British India.

	Districts.	Total number of Lepers.	Proportion of Lepers in every 10,000 [ten thousand] of the Population.
	MADRAS.		
Sea Coast Districts.	Ganjam	698	5·0
	Vizagapatam	586	4·0
	Godavari	654	4·0
	Kistna	517	4·0
	Nellore	545	4·0
	Madras	418	10·5
	Chingleput	580	6·0
	South Arcot	849	5·0
	Tanjore	1,430	7·0
	Madura	659	3·0
	Tinnevelly...	810	5·0
	Malabar	1,378	6·0
	South Canara	748	8·0
	Total	9,872	4·9
Inland Districts.	Kurnool	349	4·0
	Cuddapah	405	3·0
	Bellary	631	4·0
	North Arcot	1,253	6·0
	Salem	554	3·0
	Coimbatore	399	2·0
	Nilgiris	41	8·0
	Trichinopoly	343	3·0
	Puducottah Territory ...	97	3·0
	Total	4,072	3·6
	Grand Total ...	13,944	4·4

Divisions.	Collectorates.	Total number of Lepers.	Proportion of Lepers in every 10,000 [ten thousand] of the Population.
	BOMBAY.		
Deccan.	Khandesh	1,532	15·0
	Nasik	718	10·0
	Ahmadnagar	1,085	14·0
	Poona	1,090	12·0
	Satara	1,321	12·0
	Sholapur	795	12·0
	Belgaum	943	10·0
	Dharwar	1,155	12·0
	Kaladgi	607	7·0
	Total	9,246	11·6
Konkan.	Kanara	158	4·0
	Ratnagiri	1,237	12·0
	Kolaba	444	12·6
	Bombay	209	3·0
	Tanna	705	8·0
	Total	2,753	8·4
Gujerat.	Surat	579	10·0
	Broach	188	5·0
	Kaira	411	5·0
	Panch Mahals	114	5·0
	Ahmedabad	242	3·0
	Total	1,534	5·4
Sind.	Kurrachee...	81	2·0
	Haidarabad	126	2·0
	Thar and Parkar	8	?
	Shikarpore	87	1·0
	Upper Sind Frontier ...	7	1·0
	Total	309	1·4
	Grand Total... ...	13,842	8·5

THE LOCALITIES IN WHICH LEPROSY IS EXCEPTIONALLY PREVALENT.

It may be useful to indicate, generally, in what parts of the country leprosy is exceptionally prevalent, so that the attention of observers who may happen to reside in such localities may be arrested; and it is hoped that they may be thus induced to take a special interest in the endeavour to elucidate some peculiarities which the district or its inhabitants may present when carefully searched after. It is obvious that over such a vast area very small communities cannot be thought of in a general review, so that, perhaps, for the purpose of the present report, it will be sufficient to select such districts, or tracts of country, as are exceptionally unfortunate in this respect, which contain not fewer than, say, 100,000 souls. It may be assumed that a locality with such a population and with a proportion of lepers equivalent to 20 per 10,000—that is to say, of 1 leper to every 500 persons—is deserving of very special attention, not only for the study of the disease, but also for the purpose of devising some means whereby the troubles of the unfortunate sufferers may be mitigated.

We have, therefore, carefully examined the returns with the object of being able to bring into prominent notice all the larger districts in the three Presidencies which are burdened with such a high proportion of lepers as 2 per 1,000 implies, and have arranged the data thus collected into the subjoined Tabular Statement:—

TABLE III.

Districts of 100,000 *Inhabitants and upwards which contain a Leprous Population equivalent (or nearly so) to* 20 *per* 10,000.

Presidency.	Division or Collectorate.	District, etc.	Population of District, etc.	Total Lepers in District, etc.	Lepers per 10,000 of Population of District, etc.
Bengal ...	Burdwan ...	Beerbhoom	695,921	2,872	41·2
„ ...	„ ...	Bancoorah	526,772	1,578	30·0
„ ...	„ ...	Burdwan	2,034,745	4,604	22·6
„ ...	Kumaon ...	Kumaon and Garhwal ...	743,602	1,571	21·1
„ ...	Allahabad ...	Banda* (Tehseel)	108,771	214	19·6
„ ...	Meerut ...	Dehra Doon...	115,771	220	19·0
Bombay...	Sholapore ...	Barsi	130,853	335	25·6
„ ...	Khandesh ...	Sowda	124,519	312	25·0
„ ...	Ratnagiri ...	Rajapore	168,498	395	23·4
		TOTAL	4,649,452	12,101	26·0
Madras ...	The highest district is that of Madras itself, 10·5 per 10,000.				

The foregoing numerical data regarding the distribution of leprosy in British India, can, as already stated, be accepted as only approximately correct so far as the actual enumeration of the lepers is concerned, but what is probably of considerably more importance in connection with the study of its etiology is, that they convey fairly

* Girwain (population 78,848), in Banda District, contains 40 lepers per 10,000.

accurate information regarding the particular parts of the country where the disease is most prevalent. This is, we believe, the first attempt that has been made, or could have been made, with any prospect of accuracy, seeing that some of the most important census papers have only very recently been issued, to map out the distribution of leprosy over the Peninsula. Unfortunately, the large portion of the country which is not directly under British control must remain still undescribed. It is known to prevail in many of the districts under native rule to a very great extent, but that is all that can be said.*

The Forms of Leprosy encountered in India, and the Designations applied to it by the People.

As regards the forms of leprosy that are met with in this country, they may, we think, be classified very conveniently under the two headings generally adopted by modern writers—a classification based on the two most characteristic features of the disease. These features it will be more convenient to describe when the result of clinical observations come to be recorded; in the meantime it will be sufficient to mention generally what these leading characteristics are. In one form the most prominent feature consists in the diminished sensibility manifested over various parts of the body, and it has consequently been designated the anæsthetic form — *Lepra anæsthetica*—induced, it is believed, by a peculiar alteration in the cutaneous nerves of the part. The other leading form is commonly referred to as the tuberculated variety—*Lepra tuberculosa*—characterised by analogous changes in the skin and in other tissues, so that the parts in question present more or less tuberculated, nodular projections of various sizes and outline.

The existence of the two forms in one person forms the third, mixed variety, of some writers, but, as Virchow says, "no clear line of demarcation exists between the nervous and cutaneous forms of leprosy." We hardly think it necessary, therefore, to adopt this term as distinctive of any particular form of the disease, seeing that at best the terms "Anæsthetic" and "Tuberculated" are only used relatively according as the one or other feature characterises the phase of the malady most prominently. At the

* Whilst this Report was being printed, we had the opportunity of consulting the recently-published "Report on the Census of British Burma," from which we extract the following data regarding the number and distribution of lepers in that Province :—

British Burma.			
Division.	Population.	Number of Lepers.	Lepers per 10,000 of Population.
Arakan	484,362	185	3·8
Pegu	1,662,058	2,072	12·4
Tenasserim	600,727	946	15·7
Total	2,747,148	3,203	11·6

same time, in some instances the two symptoms are so equally evident, that it is difficult or impossible to classify them satisfactorily, and in such a case the designation "mixed" variety may be conveniently resorted to. For convenience of description, a fourth term may be adopted, as suggested by Dr. Vandyke Carter, to designate those cases in which the eruption forms the most prominent characteristic. These two may be looked upon as *varieties*. The eruption may constitute a conspicuous feature in either the anæsthetic or the tuberculated form.

The terms applied by the various populations of India to indicate the disease are not so numerous as might have been expected, considering the number of languages and dialects there are in the country. Although the works on medicine which the *hakeems*, or native practitioners, consult, recognise at least eighteen varieties of the disease, the ordinary native only recognises one or two general terms for the complaint. This seems to be due chiefly to the fact that the principal ancient treatises on medicine in this country were written in Sanskrit—a circumstance which accounts for the general uniformity in the terms adopted for the leading diseases in the different provinces. Indeed, it is probable that, with regard to leprosy, most natives in any part of India would understand what was referred to from the Sanskrit *Kushtha*, or some of its vernacular forms, such as *Kushta* (Teligu and Tamil) Kúth or *Kút* (pronounced *Koot*) or *Kúd* (Bengali, Uriyá and Assamese) and *Kút* or *Korh* (Hindi, Punjabi and Marhatti). By way of euphemism the disease is also commonly indicated by the Sanskrit terms *Roga* (vernacular *Rog*, pronounced *Rogue*), and *Vyádhi* (vernacular *Byádh*—both meaning "disease") or *Mahárog* or Mahábyádh, "the great disease." The Arabic term *Juzám* * is likewise extensively used in Northern India, and rarely, the Persian *Luri*. These terms are generally applied to the tubercular forms of leprosy, or rather to the forms characterised by the presence of deformities; whereas the more distinctly anæsthetic form is frequently described as *Sunbharri* (deprived of sensibility, Hindee). The Arabic word *Baras*, the Persian *Pes* and the Sanskrit *Dhaval* (white) are also used to designate leprous conditions, but generally these terms refer to an affection which is not leprous, *viz.*, the albino-condition of the skin described by systematic writers as *Leucoderma*—a circumstance which, as already mentioned, very greatly enhances the difficulty of obtaining correct statistics regarding leprosy proper.†

The disease‡ has been known to exist in India for at least 3,000 years, but com-

* *Juzám* is explained in the Arabic dictionaries as "a certain disease arising from the spreading of the blackbile, throughout the whole person, so that it corrupts the temperament of the members, and the external condition thereof, and sometimes ending in the corrosion, or falling off, of the members, in consequence of ulceration."

† Dr. Rájendralála Mitra, the well-known Sanskrit scholar, has, very kindly, revised the above paragraph.

‡ The "Proceedings of the Asiatic Society of Bengal," for August 1875 (p. 160), contains a very interesting communication by Bábu Rájendralála Mitra, LL.D., in reply to some questions regarding leprosy in Ancient India, put to the Society by Dr. W. Munroe. Dr. Mitra writes:—

"Taking Sus'ruta to be 400 B.C. (this date is Wilson's, I take him to be two centuries older) we must look for the date of Charaka, whom he quotes, in the sixth century B.C. Sus'ruta professes to record the lectures of his tutor Dhanvantari, and very sparingly quotes his predecessors; but his chapter on leprosy is founded on Charaka, as Dr. Munroe will easily perceive by comparing Hesseler's translation in Latin (published at

paratively little was definitely known regarding its localisation in the various parts of the country until the results of the censuses of 1872 had been published. Very important advances have within the last few years been made in the acquisition of knowledge regarding the pathology of leprosy, and it will be our duty in a future report to describe these very fully; but with regard to our definite knowledge of its actual causation, it is to be feared that we have not, except phraseologically, advanced very much on the etiological views recorded by Atreya many centuries B.C., which were to the following effect: "When the seven elements of the body become vitiated through the irritation of the wind, the bile, and the phlegm, they affect the skin, the flesh, the spittle, and the other humours of the body. These seven are the causes respectively of the seven varieties of *Kushtha*" (leprosy).

Leipzig) with the enclosed from Charaka, which I have got prepared for him. In Sus'ruta's time Charaka was an old authority of great weight, and an interval of two centuries between the two is by no means an extravagant guess. Now Charaka quotes Átreya, who was a son of Atri, a sage of great renown, who is named in the Vedas, and was the author of one of our text-books on Law. The name of Átreya occurs in Pánini, whose date Goldstücker takes to be the 9th century B.C. It is also met with in the Rig Veda Sañhitá, which dates from the 14th century B.C. Charaka also quotes Bágbhata, who, likewise, has a chapter on leprosy. Bágbhata, again, quotes Agnivesa, who was a great grammarian, and is named in the Madhukánda of the S'atapatha Bráhmana of the White Yajur Veda, and Játukarna, who is named in the Yájñavalkya Kánda of the same Veda. The works of the last two are lost, but on the authority of Bágbhata we may fairly accept them to have been professors of medicine, though it is impossible to say whether they wrote on leprosy or not. Manu mentions leprosy, but the recension of Manu we now have is supposed to be not older than the 6th century B.C. In Sus'ruta's work the word *Kushtha*, the Sanskrit name for leprosy, has been used in a generic sense, and includes several cutaneous diseases which are not leprous, but from Átreya's descriptions quoted by Charaka, it is evident that the word primarily meant leprosy. It does not occur in the Rig Veda Sañhitá, which dates from the 15th century B.C., and if we could accept this negative evidence to be of any weight, we could say that the disease was not known in the 15th century; but as there is no reason why the name of a disease should occur in a book of hymns, it is of no value; while the name of Átreya, which occurs in that Veda, and has been cited as that of an authority on the subject, would carry us much beyond the 13th century B.C., to which Dr. Munroe limits the inquiry."

"*Extract from the Charaka Sáñhitá on the Pathology of Leprosy.*

"Átreya says:—'When the seven elements of the body become vitiated through the irritation of the wind, the bile, and the phlegm, they affect the skin, the flesh, the spittle, and the other humours of the body. These seven are the causes respectively of the seven varieties of *Kushtha*. The *Kushthas* thus produced cause much pain and suffering. None of these varieties result, however, from the vitiation of a single humour. *Kushthas* are of seven, of eleven, or of a larger number of kinds; and these, constantly irritating the system, become incurable.' We shall give a brief account of these as they are produced by the vitiation of the different humours. The wind, the bile, and the phlegm, being vitiated, re-act on the skin, etc. When the wind is most vitiated it produces the *kapála kushtha*, the bile the *audumbara*, the phlegm the *mandála*, the wind and the bile the *rishyajihvá*, the bile and the phlegm the *paundarika*, the phlegm and the wind the *sidhma*, and the three together the *kákanaka*.

"Excessive physical exercise after exposure to too much heat or too much cold; taking food after surfeit; eating of fish with milk; using barley and several other grains, such as *hayanaka*, *dalaká*, *karodusá*, etc., along with venison, milk, curdled milk, and buttermilk; excessive sexual intercourse; long-protracted excessive fear or labour; fatigue, interruption of catarrh, etc.,—vitiate the phlegm, the bile and the wind; hence the skin and the three others become slackened. Thus irritated, the three elements corrupt the skin and others, and produce *kushtha*.

"The premonitory symptoms of *kushtha* are as follow: Want or excess of perspiration, roughness, discolouration, itching and insensibility of the skin, pain, horripilation, eruptions and excessive pain on the parts that are about to fall off.

"Some *kushtha* eruptions are red, rough, spreading and small; they cause horripilation, slight itching, pain, and discharge of matter and sanies. These are caused by wind, and are called *kapála-kushtha* (scaly).

"Those that are of a coppery colour, which discharge matter, blood and sanies, cause itching pain,

LEPROSY, AS OBSERVED IN KUMAON.

In accordance with instructions which we received from the Government of India, we proceeded to Almora, the headquarters of the Kumaon and Garhwal Division, early in May last, for the purpose of commencing a series of systematic observations regarding leprosy. The Commissioner, General Sir Henry Ramsay, had specially addressed the Lieutenant-Governor of the North-Western Provinces, pointing out the urgency of such an investigation, and strongly recommending the Kumaon district as peculiarly adapted for its prosecution. General Ramsay writes in May 1875: "It would be impossible to find anywhere in India so suitable a locality as Kumaon for pursuing a thorough and complete investigation into the whole subject of leprosy. At Almora we have an asylum containing on an average 100 lepers, labouring under every form and stage of the disease, whose family history can be ascertained to the minutest detail. In the district there are many hundreds either wandering alone as beggars, or residing at their homes, whose history could be gathered with perfect accuracy. Such a record would give a mass of statistics which would admit of some reliable deductions being drawn, as to whether it is possible to deal with this loathsome disease. In my opinion it is necessary that something should be attempted. If, on inquiry, it is found that nothing can be done, then it will be so far satisfactory to have ascertained that as a fact; but in the absence of that knowledge it appears to me wrong that this fearful disease should be allowed to continue to spread itself amongst the population if any measures can be taken to prevent it." In this the Lieutenant-Governor, Sir John Strachey, coincides, and adds that "the field of inquiry, while sufficiently large, will not be unmanageable in extent."

inflammation and burning, and produce worms, are also caused by wind. They appear like the ripe fig, and are hence called *Audumbara* (fig-like).

"Some are cold to the touch, raised, hard, reddish-white, clammy, itching and infested with worms. These, too, are caused by wind; they are called *Mandala* (circular).

"Those which are rough, red, white, yellow, blue, or coppery, producing itching pain, worms, burning sensation, and insensibility, are also caused by wind. They have the appearance of the tongue of an antelope, and are hence called *Rishayjihva*.

"Those which are white or red, spreading and elevated; which discharge blood, pus, and sanies, and produce itching, are also caused by wind. They appear like the leaves of the white lotus, and hence are called *Paundarika*.

"Those that are rough, red, thin, internally cold, sometimes reddish-white, which cause slight pain, itching, burning, and discharge of pus and sanies, are also caused by wind. They appear like the flowers of the pumpkin, and are called *Sidhma*.

"*Káknaka* and others have all the symptoms of *kushtha*. They are incurable, while the others are curable. That which is incurable can never be cured, and those which are curable sometimes become incurable.

"The wind causes coppery-red roughness, pain, inflammation, shrinking, horripilation, and insensibility of the skin. The bile produces burning, perspiration, pain, discharge of blood, and suppuration. The phlegm causes whiteness, coldness, itching and confluent pimples.

"The worms that form in leprous eruption destroy the flesh, skin, veins, muscles and bones. When affected by them, the patient suffers from spontaneous discharges of blood, insensibility, loss of sensibility of the skin, mortification, thirst, fever, dysentery, burning, weakness, disrelish, and indigestion. Then *kushtha* becomes incurable. The man who neglects the disease at its commencement is sure to die. He, who at the first breaking out of the disease tries to get rid of it, may be sure of its being cured."

Writing in 1874 to the India Office, the Army Sanitary Commission, in reiterating its suggestion that the whole subject of leprosy should be examined in India, says:—"The first step towards this examination is to obtain accurate statistics of the disease, such as can show not only the usual numerical data, but the precise localities where leprosy exists in India." And Dr. Gavin Milroy, who probably has a more extensive and accurate knowledge of the malady and its literature than any other writer in England, remarks, in a communication regarding the manner in which, in his opinion, the present inquiry should be conducted, as follows: "Commencing, therefore, as if the subject were a *tabula rasa*, Drs. Lewis and Cunningham will first make themselves acquainted with the natural history of the disease as it occurs in Hindustan; its essential and pathognomonic outward and physical symptoms; the circumstances and conditions which influence its origination and spread; the factors which seem to affect or modify its progress, whether beneficially or otherwise, apart from direct medication or the action of drugs, internal or external—in short, all its characteristic features and attributes. They will thus determine the general nosological nature of the malady, and whether Cullen has rightly classed it as a '*cachexia totius vel magnæ partis corporis habitus depravatus, sine pyrexia primaria vel neurosis;*' and the College of Physicians ranged it among the 'General Diseases' between Lupus and Scrofula."

We have on the present occasion endeavoured to follow out the preliminary stages of these suggestions so far as was compatible with the circumstance that, owing to the advent of the rains in July and the consequent difficulty in getting about among the hills, it was not deemed advisable to undertake any systematic personal investigation of the special localities in which the disease prevails, during the current year. This part of the inquiry we hope to be in a position to be able to report upon on a future occasion. At present we purpose restricting our remarks to such portions of the inquiry as may be comprised under the following heads:—

A—Analysis of the Statistics of the District.

1. To what extent does leprosy prevail in Kumaon?
2. Is the disease exceptionally prevalent in this district?
3. The geographical distribution of the disease in the district.
4. What are the main features in connection with the localities in which it most prevails?

B—Analysis of the Statistics of the Almora Leper Asylum, and of the results of Clinical Observations.

1. Number of lepers admitted since the Asylum was founded, and the more prominent facts concerning them generally.
2. Clinical observations regarding the persons affected with anæsthetic leprosy; 3. Tuberculated leprosy; 4. Mixed varieties of leprosy; and 5. The so-called eruptive varieties of leprosy.
6. Analysis of all the cases and deductions regarding the influence of age, sex, predisposition, etc., in the etiology of the disease.

A—Analysis of the Statistical Records regarding Leprosy in Kumaon.

1.—*To what extent does the disease prevail in the district?*

BEFORE submitting the figures regarding the distribution of leprosy in Kumaon, it will be advantageous to have a general idea of the principal physical features of the territory under consideration. The district forms a part of the North-Western Provinces, and extends in a north-easterly direction from the plains across the Southern Himalayan range to the borders of the Ari province of Tibet, and the central range. It is separated from Nepal on the east by the Kali River, and the District of Garhwal forms its western boundary, the extreme points which it touches being 29° 5′—31° 6′ north latitude, and longitude 78° 17′—80° 5′. It extends over an area of about 7,000 square miles—an area nearly as extended as the whole of Wales.

It has been truly stated that no country exhibits more extraordinary diversities of elevation, temperature and climate than Kumaon. With the exception of the low marshy land or terai which extends along its southern part, it consists for the most part of a series of mountains, some of which are among the loftiest in the world. Crystalline schists constitute the prevailing geological features. The mountains do not form a continuous ridge, but a series of hills separated by deep valleys, along which torrents and rivers course, and ultimately discharge themselves into the Ganges and Gogra. No single temperature chart of this district could be of value, seeing that the variations in its different localities are so very marked, as may indeed be inferred from the fact that there are, it is said, some thirty-four hills within its borders whose summits reach to 18,000 feet and upwards; consequently every range of temperature is to be found, from the tropical heat of the terai and the deep valleys, to an almost arctic cold.

Previous to the year 1815 the district was under native rule, but for the last sixty years it has formed a portion of the British dominions. The inhabitants are for the most part of Hindu origin, but towards the northern extremity of the country they are of Tartarian descent, and are known as Bhotias. The latter inhabit principally the slopes of the snowy range. Practically there are, besides the Mahomedans, only two castes to be found in Kumaon—Rajputs and Domes. The former, constituting the upper classes of the community, are engaged for the most part in agricultural pursuits, and the latter act as menials or carry on such trades as are considered of an inferior kind.

The habits of all classes alike are, as among most hill people, exceedingly filthy, and their villages in great part are devoid of any attempt at the observance of the ordinary rules of public health. Man and beast live in the same dwelling all the year round, the ground floor of nearly all the houses being occupied by cattle, sheep and goats. That dirt, however, is of itself sufficient to induce leprosy, is strongly contra-indicated by the fact that the Bhotias who inhabit the northern parts of

Kumaon are even dirtier than their Kumaonee brethren. It is said they never wash, such an act being considered by them as one certain to be followed by some grievous misfortune, and yet they are, we are informed, practically free from leprosy.*

The census of Kumaon has been taken on three occasions within the last twenty years—in 1852, 1864, and in 1872. The population on the last occasion was found to be 406,042, and showed an increase of 46,000 during the twenty years following the first census. This population is equal to about one-third of that of North and South Wales together, and yields a mean of 58 persons to the square mile.

TABLE IV.

Population of the District of Kumaon.

Census Returns for		
1852.	1864.	1872.
360,011	394,922	406,042

During our stay at Almora, General Ramsay very kindly placed these returns at our disposal, and appointed a clerk to transcribe the data regarding the number of lepers from the original census papers which were written in the vernacular.

These were arranged under the immediate supervision of the Officiating Junior Assistant Commissioner, Mr. G. H. Batten, to whom we are greatly indebted for the care with which he sifted the statistical records for us.

The country is divided into nineteen sub-districts or *parganas*, each of which

* The "Report on the Census of British Burma" which, as already mentioned, reached us whilst this Report was in "proof," contains the following remarks regarding the improbability of the dirty habits of the people being, in the case of the Burmese, a predisposing cause of leprosy:—"This high ratio in British Burma is deserving of attention. With reference to the conditions under which it has been observed chiefly to prevail in other countries, it may be noted that the Burmese are neither a dirty nor an under-fed people, although it has been stated that they are addicted to injudicious forms of diet. How far the consumption of unwholesome wild vegetables, and fish in a partially salted, half-putrescent state, is responsible for the presence of leprosy, it is beyond the scope of this summary to inquire."

The preparation of fish referred to is the well-known "Ngapé," which Colonel Yule thus describes:

"The paste of mashed and pickled fish, resembling very rank shrimp-paste, which is the favourite condiment of the Indo-Chinese races. It is the *Balachong* of the Malays, and the *Kapee* of Siam. Putrescent fish, in some shape or other, is a characteristic article of diet among all these races, from the mountains of Sylhet to the isles of the Archipelago. To the Chinese also, Sir John Bowring observes, fish is the more acceptable when it has a strong fragrance and flavour to give more gusto to the rice." With regard to the extent of its consumption in Burma, Colonel Yule mentions in another passage that during the year, from 1st November, 1854, to 1st November, 1855, 13,500 tons of *Ngapé* passed through the custom-house at Thayetmyo as export from British to Independent Burma.—Yule's *Mission to the Court of Ava*.

In connection with this subject, compare the foregoing with the remarks regarding leprosy in Sicily in the footnote at page 483.

may be said to correspond to a county in England; and each of these parganas again is sub-divided into *pattis*, which may be described as parishes. Each patti has one of its leading men told off who is the recognised channel of communication between the inhabitants of the villages within its boundaries and the Civil authorities. It is through these officials that the population has been estimated.

We found that there was no absolute uniformity in the data supplied from the different pattis. In some of the returns no mention is made of the presence or absence of lepers in the particular district, whereas in other returns the halt, the blind and the lepers are returned under one heading. And further, it is probable that, in the majority of instances, the cutaneous affection commonly spoken of by the people as "white leprosy"—*Leucoderma*—has also been entered in the same column. These remarks apply to all three censuses. Moreover, not unfrequently lepers have been returned as residing in certain districts when the first census was taken, and similar entries are to be found in the last census, but all mention of them in the intervening census is omitted. Notwithstanding these drawbacks, however, the information regarding the distribution of leprosy approximates to the truth with an accuracy sufficient for all practical purposes. These statistics, moreover, have probably had the advantage of closer scrutiny than any other series embracing a like area in India, as not only has the marked prevalence of the disease in the district drawn the attention of the officials generally to the matter in a special manner, but the Commissioner has for more than thirty years personally taken the warmest interest in the subject, as may be inferred from his having founded an asylum at Almora to provide shelter for such of the lepers as were homeless, and in various other ways provided for the well-being of the poor creatures all over the country who, though leprous, were not actually wandering outcasts.

It may therefore, we think, be assumed that the data upon which these statistical observations are based are of more than average accuracy, and may be taken as fairly representing the general distribution of the disease in this part of the country, as well as sufficiently precise to afford evidence whether it be on the increase or on the decline among these hills.

According to the first census that was taken of the district, there were 1,075 lepers, or very nearly equal to a ratio of 3 per 1,000, the exact fraction being 2·98. Twelve years later the actual number of lepers returned was somewhat larger, being 1,128, but the proportion to the total population slightly diminished, viz., 2·85 per mille, instead of 2·98. The returns which were received eight years later, however, showed a marked decrease both in the total numbers returned, 789, and in the proportion of lepers to the rest of the people, which, according to the census of 1872 * (see page 449), was not quite 2 per 1,000, though very nearly so.

There is little doubt, however, that these figures under-state rather than over-state the actual prevalence of the disease, for it is evident that for the most part only

* These figures differ slightly from those given in the Census Report of the North-West Provinces.

such of the lepers are entered as are actually more or less maimed by the disease. It is moreover notorious that the female lepers in a family are carefully kept out of sight, and consequently the returns regarding them are necessarily most defective. This in a great measure is the reason why the returning officers have not been able to register (on an average of all three censuses) more than one female for about every seven male lepers, although the probability is, so far as we have been able to ascertain, that female lepers are in reality nearly as numerous as male lepers in Kumaon.

It is evident therefore, for several reasons, that the figures regarding the prevalence of leprosy in this locality, as well as in India generally, can only be looked upon as approximately correct, and perhaps it would be nearer the truth were we to take the average number of lepers to the average total population in the three censuses. This average we find to be very nearly a thousand lepers for the Kumaon District (not including Garhwal), or at the rate of 2·5 per mille of the average population during the last twenty-five years. These statistical details are brought together in the accompanying table.

TABLE V.

Giving the Number of Lepers, and their Proportion to the Population, as ascertained from three Census Returns, together with the Mean of the three Returns.

KUMAON DISTRICT CENSUS RETURNS.																		
1852.					1864.					1872.*					Mean of the three Returns.			
Total Population.	Lepers.			Lepers per mille of Population.	Total Population.	Lepers.			Lepers per mille of Population.	Total Population.	Lepers.			Lepers per mille of Population.	Average total Population.	Average number of Lepers.			Average number of Lepers per mille of Population.
	Men.	Women.	Total.			Men.	Women.	Total.			Men.	Women.	Total.			Men.	Women.	Total.	
360,011	864	211	1,075	2·95	394,922	947	181	1,128	2·85	406,042	714	75	789	1·94	386,991	841·6	122·3	997·3	2·57

2.—*Is leprosy exceptionally prevalent in Kumaon?*

Assuming, therefore, that on an average 25 out of every 10,000 persons in the district are lepers, or taking the actual figures of the estimate, 1 leper to every

* These figures differ slightly from those given in the Census Report of the North-West Provinces.

388 individuals, does this indicate that Kumaon is exceptionally unfortunate in this respect? We have already commented on the distribution of the malady over India generally in the opening chapter, and have found that it was only in comparatively a very few parts of the empire that the disease attained to the magnitude implied by a ratio of 2 per 1,000; and when the entire divisions were taken, it was found that only in the division of Kumaon was this ratio exceeded. There are, however, a few *districts* in India in which the proportion is larger, especially some of the Districts (notably Beerbhoom) which go to form the Burdwan Division in Lower Bengal—a division in Bengal which alone contains nearly as many lepers as the whole of the Bombay Presidency,* so that Kumaon has the unenviable privilege of occupying a place at least in the front rank among the leprosy affected districts of British India.

With regard to the prevalence of leprosy in other countries, even the very complete Leprosy Report of the Royal College of Physicians published in 1867 contains but very few statistics, and so it is with other documents which we have examined: the writers, owing to paucity of information, have been compelled to restrict themselves "to general impressions." As is well known, the disease is in the present century less prevalent on the continent of Europe than on the other continents; nevertheless it is still endemic in many parts of Southern Europe,† and in some of the islands in the Mediterranean.

With regard to Sicily, for example, we have very recent information,‡ and the figures which have been published are of interest in connection with the relation of leprosy to the sea-coast. It has been seen that in Madras the disease is more prevalent along the coast than in the interior; the reverse, however, holds good for Sicily, for whereas the returns gave 2 lepers to every 9,000 persons living along the coast, there were 5 persons to a similar number in the interior. Many parts of India may be cited as testifying to a similar condition.

Leprosy is also endemic to a serious extent in one at least of the countries of Northern Europe, *viz.*, Norway. Fortunately we have a mass of information regarding the disease as found in that country also, of the greatest value, thanks to the labours of the numerous Norwegian physicians who have investigated the subject, and to others not belonging to that country—notably Virchow, Vandyke Carter and Neumann.

* As an example of the want of definite information regarding these matters, the following remarks from a published official letter of comparatively recent date referring to the Collectorate (Division) of Ratnagherry in Bombay, may be cited:—"I cannot tell what the number of lepers may be in other collectorates, . . . but if the statements of a report I lately read be reliable, the whole province of Bengal does not contain so many of this class of unfortunates as this single district." According to the Bombay Census Returns, Ratnagherry contains 1,237 lepers,—two per mille of population,—and the Province of Lower Bengal alone 28,403.

† There are at the present time four most characteristic cases of leprosy in the wards of the Presidency General Hospital under Dr. Coull Mackenzie who have come from Greece for the express purpose of submitting themselves to medical treatment in Calcutta.

‡ Profeta "Sulla Lepra in Sicilia," September 1875. Vide "*Jahresbericht über die gesammten Medicin*" (Virchow und Hirsch), für 1875; Band I. Seite 431.

In some respects comparisons may be instituted between Norway and Kumaon notwithstanding the difference in their position geographically, and the fact that the former is bounded on one side by the ocean; for, as Bishop Heber repeatedly observes in his *Journal*,* there are many physical features common to both; but these need not be specified on the present occasion. Norway contains about double the number of lepers that Kumaon does, but the population also of the former is more than three times that of the latter, so that the leprous population of Norway (12 per 10,000) is, in proportion, considerably lower than that of Kumaon.

With regard to the question whether leprosy is or is not on the increase in the district under consideration, it will be seen that the number of lepers actually registered in the last census was smaller than was registered in 1864. However, on looking carefully over and comparing the various entries in the detailed census returns for the several years, and taking into consideration the general impression entertained by so many of the officials in the district whom we consulted, and especially of such of the officers whose duties have constantly taken them for several years past into immediate contact with the population of even the remotest villages, we are of opinion that the number of lepers has not diminished to the extent which the last census returns imply, so that probably the earlier censuses were more exact than the last regarding this matter. The following fact appears to support this view:—

A reference to Table V on page 449 will show that in the census of 1852 the number of male to female lepers was nearly as 4 to 1, whereas in the last census the number of male was almost ten times that of the female lepers—a proportion which seems to be farther from the truth than that yielded by the earlier census.

On a future occasion we hope to be able to submit more precise data regarding this matter; at present our impression is, that although leprosy is probably decreasing in the district, the decrease is not quite to the extent suggested by the figures.

3.—*The Geographical Distribution of Leprosy in Kumaon.*

With the view of carrying out to the fullest extent practicable the suggestion of the Army Sanitary Commission already referred to, that not only the numerical data but the precise localities where leprosy prevails should be ascertained, we have kept not only the records of each pargana (= county?) distinct for itself for the different years, but also the data regarding each patti (= parish?), and every town

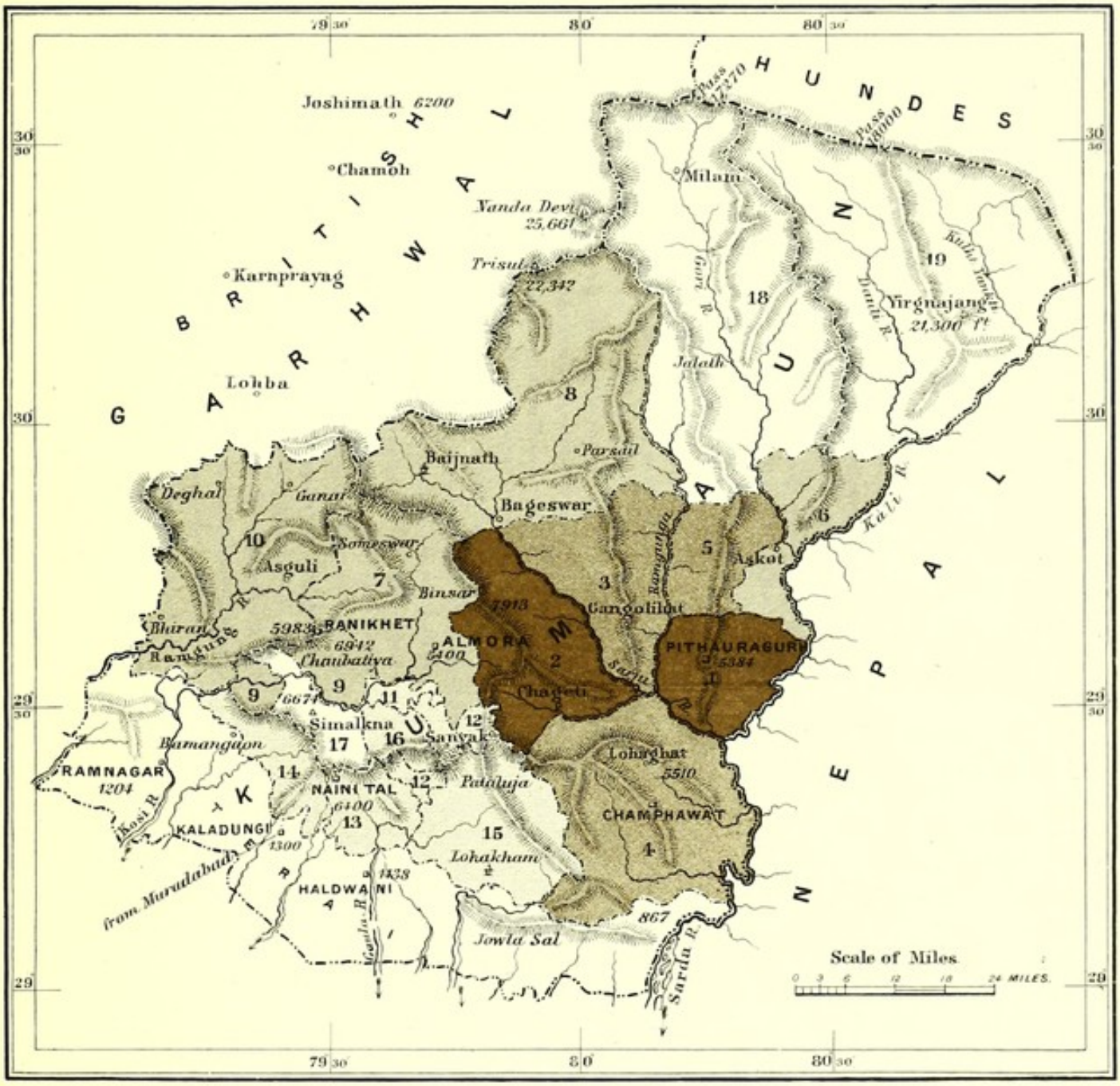
* In one of these passages the Bishop remarks: "The country as we advanced became exceedingly beautiful and romantic. It reminded me most of Norway, but had the advantage of round-topped trees instead of the unwearied spear-like outline of the pine. It would have been like some parts of Wales had not the hills and precipices been much higher, and the valleys, or rather dells, narrower and more savage. We could seldom, from the range on which the road ran, see to the bottom of any of them, and only heard the roar and rush of the river which we had left, and which the torrents, which foamed across our path were hastening to join."—*Bishop Heber's Indian Journal*, Vol. 1: 1843.

and village within its limits. The information thus collected was graphically represented on charts of the district so as to ascertain whether a more clear conception of the distribution of the malady could be obtained by this means than was obtainable by a study of the figures alone. It was our intention originally to have reproduced the greater portion of these charts, but we found that they all told pretty much the same story, and we have therefore decided on reproducing merely the chart which illustrates the distribution of the disease as deduced from the average ratios of the three censuses. We have, however, reproduced a condensed tabular statement showing the prevalence of the disease in the various parganas for all the periods mentioned, as well as the series of figures upon which the scale-shading of the map is based, which will be found in the fourth column of figures in the following table.

A glance at the figures and at the map is sufficient to arrest attention at once to the fact that leprosy prevails to a far greater extent along the eastern side of the district than along the western. This is not only the story which the figures of any particular census convey, nor yet of the average of all three censuses, but of each of them independently. As a rule, also, the most populous districts, and probably the most well-to-do, are those containing the largest ratio of lepers.

We have found it impracticable to represent graphically any information regarding the comparative prevalence of the disease in the valleys and on the hills on the present occasion. This is a question which it will be more convenient to discuss after the investigation of the localities themselves has been made. Indeed, the utmost that we can attempt at present on this point is to indicate generally the parts of the district where the malady is most prevalent.

Notwithstanding the fact that the same parganas (or counties) persistently maintain a larger ratio of such persons, a study of the figures of these censuses tends to indicate that the leprous population is a shifting one so far as the particular towns and villages which they frequent is concerned; for the papers before us show that out of an average of 574 communities which contained lepers, taking all three censuses, only 35 of all these communities are found entered as containing lepers in all three returns. This peculiarity can, we think, hardly be fully accounted for by referring it to registration errors. We have endeavoured to analyse these returns still further in order to elucidate this matter, and find that although in some places, such as shrines and the like, there is a decided tendency to the aggregation of a number of lepers, nevertheless the more general distribution appears to be pretty equal amongst the population. For example, out of the above given average of 574 communities in Kumaon associated with lepers, there were only 63 communities, taking the average of the three censuses, that contained 4 lepers, or a percentage of 4 or more. At present these facts are merely put on record because they deserve attention, but any detailed remarks which a study of them suggests will be more profitably made when the local inquiries have been completed.



MAP ILLUSTRATING THE DISTRIBUTION OF LEPROSY IN THE KUMAUN DISTRICT

(Shaded according to the Proportionate Prevalence of the Disease, in each Parganah (=County ?) .]

LEPERS PER 1,000 OF POPULATION.

PARGANAHS.			PARGANAHS.		
1 Sor 2 Chaugarkha	4 to 5 per 1,000		11 Kotauli 12 Mahryúri 13 Chhakháta 14 Kotá 15 Dhyánirau 16 Ramgarh	1 to 2 per 1,000	
3 Gangoli 4 Kálikumaun 5 Sirá	3 to 4 per 1,000				
6 Askot 7 Bárahmandal 8 Dánpur 9 Phaldákot 10 Pali	2 to 3 per 1,000		17 Dhaniyakot 18 Johár 19 Dármá	0 to 1 per 1,000	

To face p. 452.

TABLE VI.

Showing the distribution of Leprosy in each Pargana in Kumaon according to the Census of 1852, 1864 *and* 1872, *together with the Mean of the Three Returns, arranged in order of severity in each case.*

1852 Census.				1864 Census.				1872 Census.				Mean of the three Returns.			
Order of severity.	Pargana.	Total Lepers.	Lepers per mille of population.	Order of severity.	Pargana.	Total Lepers.	Lepers per mille of population.	Order of severity.	Pargana.	Total Lepers.	Lepers per mille of population.	Order of severity.	Pargana.	Average total number of Lepers.	Average number of Lepers per mille of population.
1	Sor	109	5·94	1	Chaugarkha	178	6·07	1	Chaugarkha	99	3·77	1	Chaugarkha	132	4·83
2	Chaugarkha	121	4·74	2	Sor	96	5·05	2	Kali Kumaon	168	3·52	2	Sor	93	4·82
3	Sirá	19	4·20	3	Gangoli ...	74	3·74	3	Sor	76	3·47	3	Gangoli ...	64	3·37
4	Ramgarh ...	18	3·70	4	Bárahmandal	209	3·31	4	Gangoli ...	62	3·10	4	Kali Kumaon	139	3·04
5	Bárahmandal	203	3·49	5	Phaldákot ...	52	3·19	5	Sirá	22	2·66	5	Sirá	20	3·00
6	Gangoli ...	56	3·29	6	Dánpur ...	62	3·01	6	Askot ...	15	2·44	6	Askot ...	15	2·79
7	Askot ...	15	3·11	7	Askot ...	17	2·88	7	Dánpur ...	51	2·02	7	Bárahmandal	174	2·71
8	Káli Kumaon	138	3·05	8 9	Kotauli Mahryúri	32	2·66	8	Kota ...	1	1·95	8	Dánpur ...	54	2·59
9	Dánpur ...	49	2·97	10	Sirá	21	2·60	9	Bárahmandal	110	1·67	9	Phaldákot ...	40	2·49
10	Phaldákot ...	40	2·77	11	Páli	246	2·59	10	Phaldákot ...	28	1·54	10	Páli	19	2·10
11 12	Kotauli Mahryúri	30	2·67	12	Káli Kumaon	111	2·51	11	Páli	123	1·31	11 12	Kotauli Mahryúri	22	1·64
13	Páli	211	2·42	13	Kotá ...	9	1·95	12	Dhyánirau ...	16	0·91	13	Chhakháta ...	9	1·20
14	Chhakháta ...	13	1·79	14	Ramgarh ...	6	1·16	13	Chhakháta ...	5	0·65	14	Kota ...	5	1·25
15	Dhaniyakot...	17	1·48	15	Dárma ...	3	0·62	14 15	Kotauli Mahryúri	6	0·49	15	Dhyánirau ...	19	1·10
16	Dhyánirau ...	22	1·28	16	Johár ...	6	0·60	16	Johár ...	4	0·38	16	Ramgarh ...	5	1·00
17	Koti	5	1·06	17	Dhaniyakot...	6	0·47	17	Ramgarh ...	1	0·19	17	Dhaniyákot...	8	0·70
18	Johár ...	9	0·96	18	Chhakháta ...	?	?	18	Dhaniyakot...	2	0·17	18	Johár ...	6	0·64
19	Dárma ...	?	?	19	Dhyánirau ...	?	?	19	Dárma ...	?	?	19	Dárma ...	3	0·62

4.—*What are the main features in connection with the localities in which it is most prevalent?*

Having seen that three out of four leading questions which we set ourselves at starting may be replied to pretty conclusively from a study of the statistics alone,—*viz.*

(1*st*), to what extent are the inhabitants of the district of Kumaon affected with leprosy; (2*ndly*), whether this district is affected in an exceptionally severe manner; and (3*rdly*) whether the disease is more prevalent in any particular portion of it; the fourth question suggests itself naturally out of the reply to the third,—namely,—To what may the ascertained prevalence of the disease along the eastern side be attributed?

Seeing that we purpose going over these particular portions of the district, it will be best to defer all reference to the physicial features of the locality which records might supply until we shall have been able to obtain information for ourselves regarding them: but one feature we cannot avoid directing attention to even thus early in the course of the inquiry; and that is the fact that the portions of the district which are specially affected are directed towards the Nepal frontier.

Although our exact knowledge of the distribution of disease in Nepal is exceedingly meagre, on account of the hindrance offered by the Nepal authorities to the exploration of the country by Europeans, still it is well known that leprosy does prevail to a large extent in that territory. The neighbouring Nepalese and the Kumaonese are for the most part derived from the same stock; the hills and valleys which they inhabit are alike, and so are their habits; and it is highly probable that the customs which prevailed for many centuries in Kumaon during the reigns of the local rajahs until 1790, and subsequently under the rule of the Goorkhas, until they in their turn were ejected by the British in 1815, continue unmodified, or modified to a very trifling extent only, in these portions of Nepal at the present day. Now, with regard to the custom of the country in connection with leprosy, we have very trustworthy information that when a person became a confirmed leper he somehow disappeared, and there were no questions asked. They were supposed to have buried themselves. This state of affairs of course disappeared with the accession of British rule, but as British authority does not extend beyond the River Káli, it seems not improbable that the Nepalese lepers, foreseeing a possible contingency, cross this river, and thus avail themselves of the protection of a more humane government. It appears to us, therefore, not to be a circumstance to create surprise to find that the Nepal side of our territory should be thus exceptionally frequented by lepers. This deduction is strongly supported by the somewhat remarkable circumstance that, notwithstanding the distance between Almora and the Nepalese frontier, one-fifth of all the lepers who have obtained shelter at the asylum during the last thirty years came from Nepal.

B—Observations conducted at the Almora Leper Asylum.

HAVING in the previous section discussed some of the general questions relating to the existence and prevalence of leprosy in Kumaon, we now proceed to give an account of the information derived from an examination of the present inmates and past history of the Leper Asylum at Almora.

The Asylum has now been in existence for upwards of thirty years, and there can be no question as to the benefit which Sir Henry Ramsay has conferred on the

people of Kumaon in establishing and supporting the institution. Lepers, although in some cases kindly treated by their friends, are no doubt in very many exposed to great ill-usage. The aversion with which they are regarded, and the disgrace attaching to the occurrence of the disease in a family, are inducements to make outcasts of them, and the temptation to do so is increased by interested motives, as by turning them adrift, their relatives are enabled to appropriate to their own use the share of the family property belonging to the sick. Under these circumstances an asylum, utterly apart from benefits due to medical treatment, is a great blessing to the unhappy lepers, affording them a shelter in which they may live in comparative comfort, in place of wandering at large over the country as beggars. In striking proof of this is the rarity with which leprous beggars, in spite of the prevalence of the disease, are to be encountered in the neighbourhood of Almora, as well as the contented and even cheerful spirit displayed by the vast majority of the inmates of the Asylum, which cannot fail to be remarked by all who are aware of the miserable and depressed condition of similar cases occurring in places where no proper accommodation is provided for them.

We are under great obligation to the Honorary Superintendent of the Asylum, the Reverend J. H. Budden, for the readiness with which he aided us in ascertaining the fullest particulars regarding the institution and its inmates, as also to all the officers who were in any way connected with the Asylum.

1.—*Summary of the Statistical Records of the Asylum.*

The following tables show the principal facts in the history of the Asylum, relative to admissions, number of inmates, mortality, etc., obtainable from the registers kept in the institution.

TABLE VII.

Number of Male Lepers admitted into the Leper Asylum at Almora, with the numbers of those who have died, of those who have left the Asylum, and of those remaining in it.

Years.	Total male lepers admitted.	Years in which deaths occurred.											Left the Asylum.	Remaining in the Asylum.
		1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Total deaths.		
Previous to 1866 ...	13	...	...	...	...	...	...	...	1	2	1	...	4	3	6
1866	2	...	...	...	...	...	...	...	1	...	...	...	1	...	1
1867	3	...	...	...	...	...	...	...	1	2	...	...	3	...	...
1868	10	...	...	...	...	...	...	1	1	2	1	...	5	3	2
1869	7	...	...	...	...	...	...	1	1	...	...	...	2	...	5
1870	11	...	...	...	...	...	...	2	3	...	1	1	7	1	3
1871	14	...	...	...	...	...	...	2	...	4	...	...	6	6	2
1872	12	...	...	...	...	...	...	1	2	1	...	...	4	4	4
1873	16	...	...	...	...	...	...	...	6	2	...	...	8	2	6
1874	17	...	...	...	...	...	...	...	...	4	...	...	4	7	6
1875	11	...	...	...	...	...	...	...	...	...	2	1	3	1	7
1876	11	...	...	...	...	...	...	...	...	...	...	1	1	2	8
Total	127	...	...	...	...	...	...	7	16	17	5	3	48	29	50

TABLE VIII.

Number of Female Lepers admitted into the Asylum at Almora, with the numbers of those who have died, of those who have left the Asylum, and of those remaining in it.

Years.	Total female lepers admitted.	YEARS IN WHICH FEMALE LEPERS DIED.											Left the Asylum.	Number remaining.
		1866.	1867.	1868.	1869.	1870.	1871.	1872.	1873.	1874.	1875.	1876.	Total deaths.	
Previous to 1866 ...	23	...	...	...	...	...	...	1	4	1	4	...	10	2	11
1866	2	...	...	...	...	...	...	...	...	...	1	...	1	...	1
1867	3	...	...	...	...	...	...	...	...	1	2	...	3	...	...
1868	3	...	...	...	...	...	...	1	...	...	1	...	2	...	1
1869	2	...	...	...	...	...	...	...	...	...	...	...	...	...	2
1870	5	...	...	...	...	...	...	...	...	...	...	...	...	1	4
1871	9	...	...	...	...	...	...	...	...	1	2	...	3	1	5
1872	7	...	...	...	...	...	...	2	1	...	...	...	3	3	1
1873	8	...	...	...	...	...	...	...	1	1	...	...	2	4	2
1874	8	...	...	...	...	...	...	...	...	3	...	...	3	2	3
1875	8	...	...	...	...	...	...	...	...	...	...	1	1	1	6
1876	6	...	...	...	...	...	...	...	...	...	...	...	...	...	6
Total	84	...	...	...	...	...	...	4	6	7	10	1	28	14	42

During the entire period in which the Asylum has been in existence, 211 patients —127 males and 84 females—have been received into it up to the end of June 1876. Since 1866, from which date alone accurate registration has been conducted, the numbers present in the Asylum in any year have, on an average, amounted to 97·2, ranging from 106 in 1869 to 85 in the commencement of the current year. The numbers annually admitted have varied from 4 in 1866 to 25 in 1874. Previous to 1866, 13 males and 23 females were admitted. Since that time the number of males admitted has, almost every year, largely exceeded that of females—a fact which is no doubt greatly due, as has been already pointed out in regard to the census returns, to a greater tendency to conceal the occurrence of the disease when occurring in females. Of the total of 211 cases admitted, 43 have left the Asylum at various dates and 76 have died. As the patients are under no restraint, the comparatively small number leaving speaks well for the comfort enjoyed by the inmates.

The deaths since 1866 have varied from 24 in 1874 to 11 in 1872. No deaths have been recorded as having occurred between 1866 and 1872, but 36 per cent. of the total cases admitted, or 45·2 per cent. of the admissions after deducting those leaving the Asylum, have died since 1872. The causes of death in the various years cannot now be determined, as, until quite recently, there was no medical establishment connected with the institution. This is to be regretted, as the fluctuation in the number of deaths is very considerable. Such an absence of information fortunately cannot occur again, as the Asylum is now under the supervision of a medical officer, and has a

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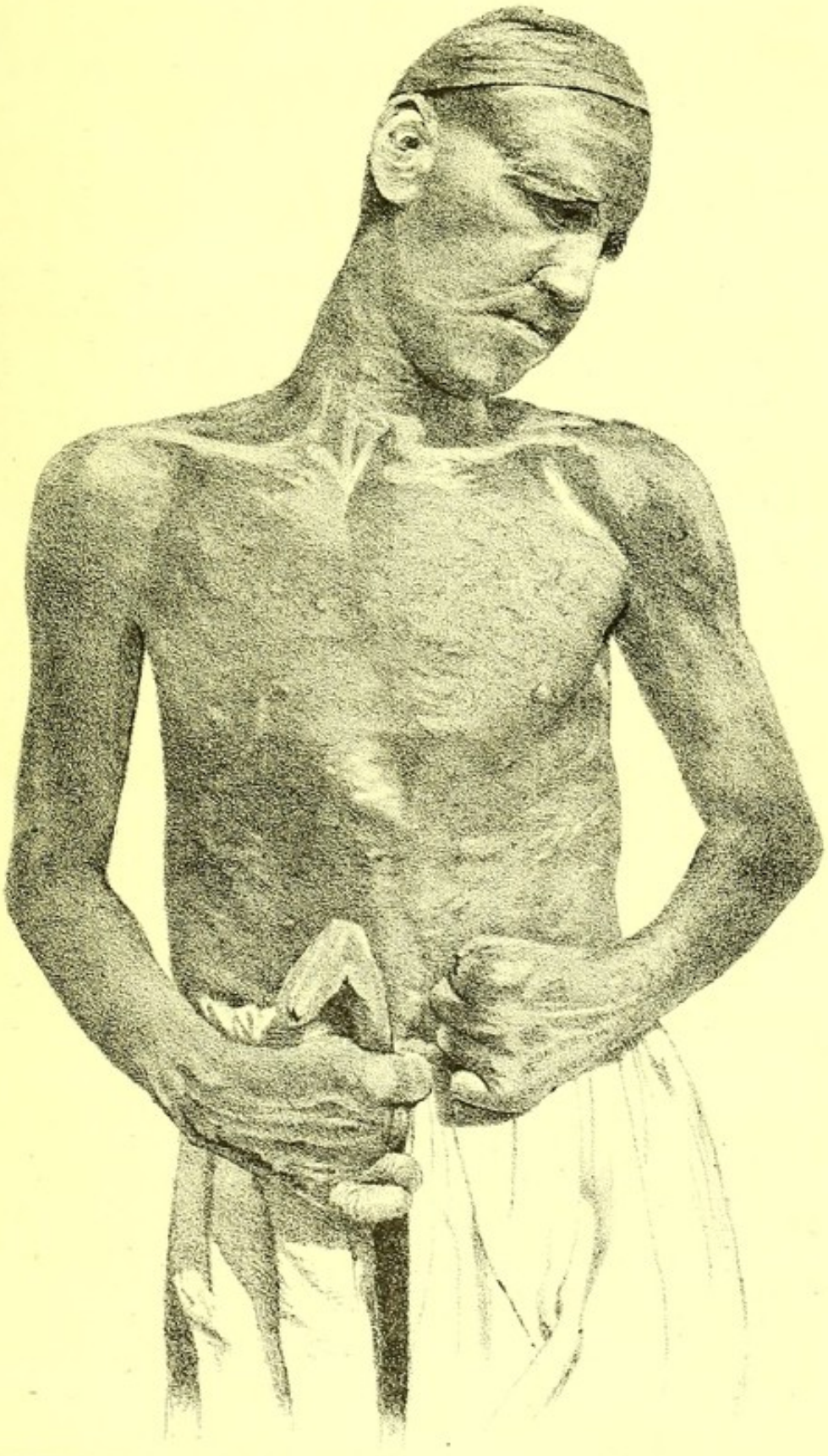
From a Photograph.

ANÆSTHETIC FORM OF LEPROSY—The Eruption.



From a Photograph.

To face Plate XXIX.

ANÆSTHETIC FORM OF LEPROSY—Destruction of Fingers.

[The same Patient as in Plate XXIX.]

resident native doctor attached permanently to it. Of the 36 lepers admitted into the Asylum previous to 1866, 14, or 38·8 per cent., are dead; the rest, with the exception of 5, are now in the Asylum. Of the 175 cases admitted since 1866, 62, or 35·4 per cent., have died, 38 have left the Asylum, and 75 remain. That the percentage of deaths should be so nearly equal in the two cases is no doubt owing to the fact that the majority of deaths occur among recent admissions, and are probably due to the tuberculated form of leprosy, which is known to run a more rapid course than the anæsthetic form. The number of inmates of the Asylum during our visit was 80, excluding a few spurious or doubtful cases.

All the recognised forms of true leprosy are represented among the inmates, although in very unequal proportion, there being 49 cases in which anæsthetic phenomena form the prominent symptoms, 12 in which the tubercular element prevails, 4 in which eruption is very conspicuous, and 15 in which tuberculated and anæsthetic phenomena are so closely and equally associated that they may with propriety be regarded as cases of the "mixed" variety of leprosy.* This division of the cases is, however, to be regarded as a relative one only, founded on predominance of symptoms. The cases classed as "anæsthetic" were invariably, or almost invariably, comparatively pure cases of this form; but in advanced cases of tuberculated leprosy, the phenomena are very rarely, if ever, dissociated from more or less pronounced symptoms of anæsthesia, so that they might generally be included under the heading of mixed cases. Still the one condition was so much more strongly marked than the other, that it appeared warrantable and conducive to clearness to retain them under a distinct heading. The same holds in regard to those classed as "eruptive," the very small proportion of which cases is noteworthy, and is probably, in part at all events, to be ascribed to the fact that patients do not generally present themselves for admission until the disease has lasted for some time, and until, in consequence, eruptive symptoms have disappeared, or have been obscured by the development of anæsthetic or tuberculated phenomena. This is the more probable as, in the vast majority of cases, the patients suffering from advanced tubercular or anæsthetic symptoms described their disease as having commenced with the occurrence of an eruption.

Whilst at Almora we endeavoured to select typical examples of the two leading forms of leprosy for the purpose of illustrating their more prominent features. Several such cases were photographed, but we have thought that three would be sufficient for our present purpose. Reproductions of these accompany the present report.

Speaking generally, the plates may serve as illustrations both of the anæsthetic and tuberculated forms of the disease. The eruption presents a prominent feature in the case which we selected of the former (Plate XXIX), especially on the dorsal surface of the trunk; but numerous little nodular elevations may also be observed when the photograph of the chest of the same individual is closely examined (Plate XXX). It

* These figures do not give a total corresponding with that derived from the tables of admissions, due to the fact that a few doubtful cases are inmates of the Asylum.

will also be remarked that almost complete absorption of the fingers has taken place. In the figures of the thirty-first plate the tuberculated feature is the leading characteristic. Figure 1 (Plate XXXI) represents an almost typical instance of the *Leontiasis* of the Ancients. The lips are thickened; the skin of the forehead is thrown into nodular folds separated by deep furrows; the eyebrows and lobes of the ears are enormously thickened, as are also the *Alæ Nasi:* the latter are seen to have acquired a trefoil-like aspect. In Fig. 2 (Plate XXXI) the thickening of the lips and ears, and the sinking of the *septum nasi*, owing to the disease of the mucous membrane and cartilages of the nose, are conspicuous. In addition there is an angry lupus-looking ulcer of the cheek which had produced even more distortion of the features than is suggested by the plate. These cases will be subsequently referred to when detailing the clinical observations.

In proceeding to details, we shall first give an account of the facts ascertained in reference to each class of cases separately, and shall then proceed to the consideration of those questions common to the disease generally.

2.—*Analysis of cases in the Asylum affected with Anæsthetic Leprosy.*

This is, as has been shown above, much the commonest form of the disease among the inmates of the Asylum.

The distribution and extent of the anæsthesia present varied extremely in different cases. Taking the forty-nine cases, the general distribution of the anæsthesia is shown in the following statement:—

TABLE IX.

Showing the Distribution of Anæsthesia in 49 Lepers.

Cases.	ANÆSTHESIA OF						
	HEAD AND NECK.				Upper Extremities.	Lower Extremities.	Trunk.
	Face.	Ears.	Scalp.	Neck.			
49	36	28	12	6	48	49	21

In this statement we find that in 36 cases there was more or less complete anæsthesia of the face, that in 28 the ears, in 12 the scalp, in 6 the neck, in 48 the upper, in all the lower extremities, and in 21 the trunk, were affected. In 2 cases the ears were affected without their being any anæsthesia of the face, so that the cases in which the head and neck were affected amounted as a total to

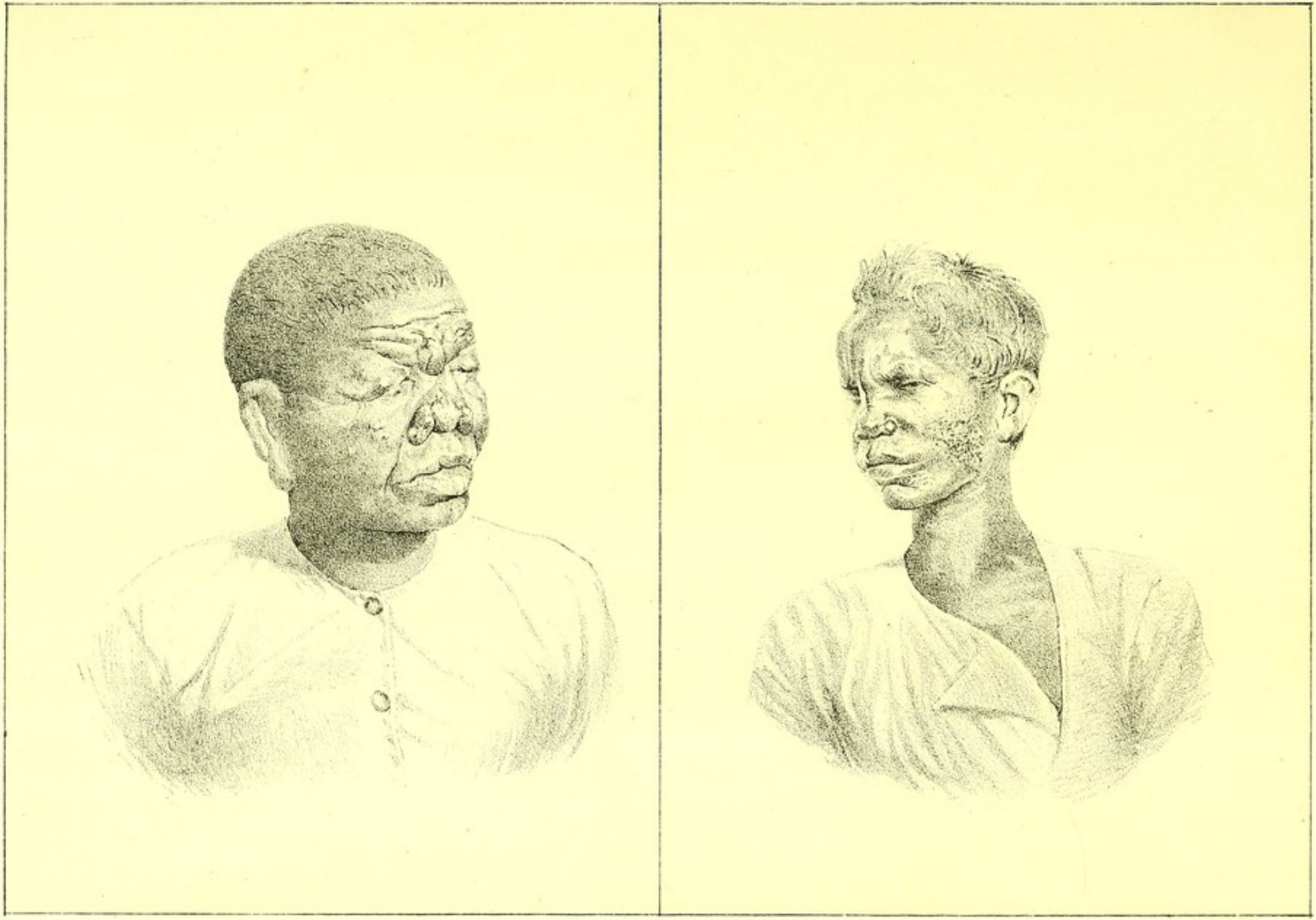


Fig. 1. From Photographs. Fig. 2. *To face p.* 158

TUBERCULATED FORM OF LEPROSY.

38. Taking the regions of the entire body in order of number of cases, we find the lower extremities occupying the first place, followed successively by the upper extremities, the head and neck, and the trunk, the latter being only a little more than half as frequently affected as the face.

Proceeding to a more detailed account of the distribution of the anæsthesia, we shall take up its several localities in the order of the table.

1. *The face.*—In 20 cases the anæsthesia was complete over the entire face. In those cases in which it was partial only, the precise distribution varied; in one case it was confined to the malar prominences, in another to the right malar prominence and the centre of the forehead, while in a third there was complete anæsthesia of one side of the face, the other remaining unaffected. The chin alone escaped in 3 cases, along with the upper lip in another, and with the upper lip and the angles of the lower jaw in a third. In 2 cases the forehead alone, in 1 the forehead and the upper lip, and in 1 the temporal regions alone escaped. In 4 cases the precise distribution was not determined.

2. *The ears.*—In 18 cases these were entirely anæsthetic. In 1 there was complete anæsthesia of the left ear only; in 5 sensibility was impaired, although not absent; in 2 the tragi and interior surface of the ears escaped; in 1 the interior of both ears with the tragus of the right, and in another the interior of the right ear alone escaped.

3. *The scalp.*—In 8 cases anæsthesia was complete over the entire forehead. In 1 it extended from the forehead halfway to the occiput; in 1 it was present on the left side only, and in 1 a certain amount of sensibility was retained throughout. In 1 case the precise distribution was not determined.

4. *The neck.*—Anæsthesia of the neck when present was in all cases complete over the entire region, and its occurrence was always associated with very widely diffused and extreme anæsthesia of the body generally.

5. *The upper extremities.*—In 20 cases the entire upper extremities from the shoulders downwards were completely anæsthetic. In 13 cases anæsthesia was complete from the elbows, in 2 complete from the elbows save over the hollow in front of the joint. In 1 case it was confined to the extensor surfaces from a little above the elbows, and in another was complete from the elbows on the extensor and only partial on the flexor surfaces. In 1 case the entire upper extremities, save the ball and inner margin of the left thumb, were affected; in one the entire extensor surfaces with the flexor surfaces from a little above the elbows. In 1 case anæsthesia was not present save over the upper third of the inner surfaces of the arms. In 1 case it was complete from the mid-forearms; in 1 it was complete from the elbow downwards on the right side, but on the other was confined to the hand; in 1 it was present from the elbow downwards on the right side for the entire surface, on the left for the extensor surface only. In 1 case the left extremity was entirely anæsthetic, whilst the upper portion of the right arm retained

sensation. In 1 the hands alone were affected, in 1 the extensor surfaces alone from a little above the elbow. In 1 the extensor surfaces throughout and the entire hands, save the tips of the fore and ring fingers and the ball of the right thumb, were anæsthetic; in another the anæsthesia was complete, save over the upper third of the inner surfaces of the arms. In no cases were the arms affected without the forearms; in 1 there was no anæsthesia present; in 1 only it was confined to the hands, and in 5 there was evidence of a greater liability to disease of the extensor as compared with the flexor surfaces.

6. *The lower extremities.*—In 18 of the 49 cases the entire extremities were affected; in 15 complete anæsthesia was present from the knees downwards; in 1 the condition was similar, save that the areas corresponding with the lower half of the popliteal spaces were sensitive. In 4 cases complete anæsthesia was present from the mid-thigh; in 1 from mid-thigh anteriorly, and over the entire posterior surface, save the popliteal areas. In 3 cases there was complete anæsthesia from the knees with diminished sensibility of the thighs; in 2 the anæsthesia was universal, save over the upper third of the inner surface of the thighs; in one it was complete over the entire surface externally and posteriorly, and from the ankles only on the inner surface. In 1 case the popliteal area of the right side alone escaped. In 1 anæsthesia was present from the upper third of the legs, in 1 from the ankles, and in 1 confined to the feet.

7. *The trunk.*—In 5 cases the entire surface of the trunk was completely anæsthetic, and in another the patient affirmed this to be the case, although at the same time distinct twitching of the surface followed irritation. In 4 cases sensibility, although much diminished, was not absent, and in 1 of these the posterior was less affected than the anterior surface. In 1 there was partial anæsthesia passing into total absence of sensation over the gluteal regions; in 1 there was complete anæsthesia anteriorly, and in another complete anæsthesia posteriorly. In 1 anæsthesia was confined to the shoulders; in 4 to the gluteal regions; in 1 to the left gluteal region; in 1 to the loins; and in another to a patch behind the spleen.

The general results of this analysis of cases illustrate the well-known tendency to peripheral over central localisation of the affection, and also clearly demonstrate the distribution of anæsthesia according to nervous areas. One of the most interesting points noticed is that in reference to the ears, apparently indicating that the internal surfaces and the tragi are less liable to suffer than the rest of the ears, implying a corresponding comparative exemption of the auriculo-temporal nerve as compared with the other nerves supplying the external ear. The distribution according to nervous areas is also illustrated by other phenomena—by the exemption of the upper lip and chin, by the sharp limitation of anæsthesia to the line of the lower jaw and to the gluteal regions on the trunk, by the greater liability of the extensor as compared with the flexor surfaces of the upper, and of the outer with the inner surfaces of the lower extremities.

Having thus discussed the phenomena of the diminution, or disappearance, of the sensibility of the external surface of the body, there yet remain one or two anæsthetic and other nervous symptoms to be noted in reference to the cases. The condition of the tongue and fauces in relation to common and special sensation was inquired into in numerous cases. As a rule, both touch and taste, according to the patient's account, remained intact, and only in very advanced cases was there any evidence of loss of either. In one case the tongue was anæsthetic to touch, but the sense of taste was retained, whilst in another the reverse condition was present.

In 4 cases only did the patients complain of any pain, in spite of the great prevalence of open ulcerating surfaces among them. In one the sites of pain were referred to the inner side of the right and outer side of the left calves, extending to the knee-joints, and a certain amount of prominence of the cutaneous nerves over corresponding areas could be detected. In another case pain was complained of along the inner sides of both calves, in a third the big toes were painful, and in another the pain was connected with ulcerations of the soles of the feet. In several other cases, although no general complaint of pain was made, the exposed surfaces of the phalanges of the fingers and toes were tender and painful when touched. That pain cannot be a common or troublesome accompaniment of leprosy among the inmates of the Almora Asylum is sufficiently evident from the happy and cheerful demeanour manifested by the majority of them.

Dimness of vision was complained of in one case. The eyes showed no external signs of disease, but as an ophthalmoscopic examination could not be made it remains uncertain whether or not this were due to the existence of deposit on the retina. In one very advanced case the patient was blind, but this was due to opacity of the cornea.

In 1 or 2 cases there were obvious thickenings along the course of the cutaneous nerves supplying anæsthetic areas. The skin in many instances showed no special indications of disease apart from ulcerations or the cicatricial traces of former ones. In 17 cases, however, there were more or less decided alterations in the skin over the surface of one or other portion of the body. The commoner forms of these were general shrivelling and puckering of the surface, which at the same time presented a peculiarly dry aspect; the occurrence of coarse folds of skin about the elbows and knees; the presence of fissures in the hands, and more especially in the soles of the feet, and the occurrence of discoloured patches of various extent. The cause of the shrivelled and folded condition of the skin is no doubt to be ascribed in great part to partial atrophy and diminution in bulk of the subjacent muscles, and may in part also be due to affection of its intrinsic muscular elements. The cracking of the skin is a very common symptom, and is, as we shall see, frequently the first to warn the patient of the onset of disease. The patches of discoloration were sometimes of a whitish hue, and were then usually situated about the elbows, knees, hands, and feet. In 3 cases there were large irregular

patches of light discoloration, probably the remains of leprous eruption, over the back and shoulders; and in one the same regions were occupied by similar patches of pinkish colour. In 1 case the hands and feet were swollen and scaly, and in another a scaly eruption was present over the ankles. In 2 cases there was a very peculiar bluish cyanotic hue of the palms of the hands.

In 1 case there was marked enlargement of the inguinal glands. In 35 cases open ulcers were present, sometimes on both the hands and feet, very rarely on the hands alone, frequently on the feet alone. They were in many ascribed to burns or other injuries incurred, due to the anæsthetic condition of the affected surfaces, and this probably is the explanation of their more frequent occurrence on the feet. In most cases they were said to heal readily and easily, which, with the phenomena frequently attending their causation, points to the non-specific or essentially leprous nature of many of such ulcers, not being dependent on the breaking down of any deposit, but merely due to accidents or mal-nutrition induced by the effects of such deposit elsewhere. This is a point on which Virchow lays particular stress.* The inference is also borne out by the microscopic examination of the discharges from such ulcerating surfaces, for, in so far as we could ascertain from those cases in which we examined such materials, they contain no special cells or other morphological elements not common to any non-specific ulcerating surfaces.

In only 3 cases was there an entire freedom from ulceration or absorption of the digits of both hands and feet. In all the rest one or other condition was present in greater or less degree, sometimes affecting the hands or even one hand only, whilst the feet escaped, in others having a reversed distribution, but in the vast majority affecting both upper and lower extremities simultaneously. The degree to which the affection of the digits was present varied greatly, ranging from mere cracks and superficial ulceration of the tips of one or two fingers or toes up to the total absence of the whole of all of them, and in some cases even to partial disappearance of one or more metacarpal bones (*vide* Plate XXX). In most cases the mutilation appeared to have been caused by progressive ulceration or by necroses *en masse* of one or more joints at a time, but in some the digits appeared rather to have been removed by a process of interstitial absorption, as the nails in a more or less entire condition, adhered to the remnants of hands or feet which still persisted.

In many cases the remaining digits were strongly contracted, the contraction in some instances causing most curious distortions, as in those where there was permanent flexion of the proximal phalanges with extension of the distal one of one or more fingers—a condition present in several instances.

In advanced cases of long duration there was frequently, in addition to distortion due to contraction, extreme muscular atrophy, the entire muscles of the ball of the thumb and palms of the hands appearing to have disappeared, leaving the bony framework covered by the skin alone. This was especially remarkable in one or

* *Die Krankhaften Geschwülste.* Zweiter Band; Seite 529.

two old cases in which the disease had lasted for many years unaccompanied by much distortion or destruction of the hands.

The voice was more or less altered and husky in 7 cases. In 5 of these the nose was sunken, and in several it was difficult to determine whether the condition was not due rather to syphilitic than to leprous disease. In 2 at all events there could be little doubt in referring it to syphilis; in 1 of these there was most offensive ozæna, and in the other the depression of the nose was affirmed to have preceded the leprous symptoms.

The blood of the patients was microscopically examined in 28 cases. In 17 of these it was to all appearance perfectly normal, in the remaining 11 it was characterised in 5 instances by a greater or less excess of normal white corpuscles and bioplastic fragments of small size, in 3 by such excess combined with a softened gelatinous condition of the red corpuscles causing them to adhere in irregular masses, and in 3 by the latter phenomenon alone. In 2, specimens of blood could only be with difficulty obtained from the hands. One of these was a case in which the characters of the specimen were normal; the other, one in which the red corpuscles were softened. In both cases the difficulty seemed to arise from the presence of much condensation of the tissues at the site of puncture due to absorptive and cicatricial changes there. In most cases the blood was obtained with ease, and in some there was an excessive tendency to hæmorrhage on the slightest provocation.

These are the principal phenomena noted in regard to the condition of the subjects of anæsthetic leprosy in the Asylum, and it now remains to consider one or two more general points in their history.

Sex.—Of the 49 cases of the anæsthetic variety of the disease, 25 were males and 24 females, giving respectively a percentage of 54·3 and 70·5 on the total male and female leprous population of the Asylum.*

Age.—The ages of the patients ranged from 17 to 63, the average of all being 40·9. In regard to this as well as in regard to the age of attack, and consequently of the duration of disease, the data are avowedly imperfect and to be taken as only relatively correct, as the natives of India are habitually so ignorant of their actual age and so incorrect in their estimates of time, that no reliance can be placed on the accuracy of their statements on such subjects. Taking the figures as they are the earliest date of attack is 8 years, and the latest 60. Of the 40 cases 5 are said to have commenced under 10 years of age, 12 between 10 and 20, 12 between 20 and 30, 13 between 30 and 40, 3 between 40 and 50, 3 between 50 and 60, and 1 at 60.

The average age of attack for the 49 cases is 26·18. The duration of disease from the date of attack until the period of examination ranged from 1 to 40 years. That of 16 was under 10 years, of 15 between 10 and 20 years, of 16

* These percentages refer to the distinctly leprous inmates only.

between 20 and 30, of 1 32 years, and of 1 40 years. In regard to the latter case, the disease appeared almost in abeyance, having apparently run its course, and left the patient suffering from the effects of former rather than from the existence of present disease. There could be no doubt as to the prolonged course of the disease in this instance, as the patient has been for 32 years an inmate of the Asylum. The average duration for the 49 cases was 15·22 years.

The question of the existence of leprosy among the patients' relatives was carefully inquired into with the following results. In 18 of the 49 cases of the anæsthetic form of the affection, or 36·7 per cent., the patients allowed that they had, at the time of examination or formerly, leprous relatives. The nature of the relationship is shown in the following statement:—

TABLE X.

Cases of Anæsthetic Leprosy with leprous relatives.

No.	Nature of Relationship.			
	Parents.	Brothers or Sisters.	Children.	Other Relatives.
1	Both	3 Brothers.		
2	„			
3	„			
4	Mother	1 Sister.		
5	„	1 Brother ...	...	Mother's brother.
6	„			
7	„			
8	„			
9	„			
10	... ...	1 Brother.		
11	... ...	„		
12	... ...	„		
13	... ...	„		
14	... ...	... ...	4 Sons.	
15	... ...	... ...	...	Father's father.
16	... ...	... ...	...	„ brother.
17	... ...	... ...	...	„ „
18	... ...	... ...	...	Sister's child.
Total... 18	9	7	1	5

The questions connected with family predisposition and heredity of the disease will be again recurred to in reference to the lepers in general apart from the form of the disease.

The information attainable regarding the first symptoms of onset of the disease is like that regarding questions of age and time, only worthy of qualified acceptance. In 3 cases the patients could give no account of their malady; in 17 it is said to have been attended by the appearance of red patches of eruption on different parts of the body; in 5 by similar patches of a pale colour; in 8

by patches of eruption accompanied by cracking of the heels; in 1 by eruption and the appearance of bullæ on the feet; in 5 by cracking of the soles of the feet; in 1 by pain and cracking of the skin over one ankle; in 3 by the appearance of bullæ on various parts of the body; in 2 by ulceration of the extremities; in 2 by the appearance of abscesses; in 1 by whitlow and necrosis of one of the fingers; in 1 by swelling and pain of the toes. If any conclusion is to be arrived at from these statements, it is that the commonest symptom attracting attention to the commencement of the disease is an eruption of some form, such having occurred, it is affirmed, in 31 of the 49 cases.

3.—*Analysis of the cases in the Asylum affected with the Tuberculated form of Leprosy.*

There were 12 cases, or 15·0 per cent. of the total cases, in which nodular appearances were by far the most prominent features in the disease. Of these 10 were males and only 2 were females, or 21·7 per cent. and 5·8 per cent. respectively on the total lepers in the Asylum.

Distribution of the nodules.—In all these cases the face and ears were the seats of tubercular deposit. In all save two the deposit there was extensive, and exceeded that in other sites. In 1 only was tubercular deposit in the extremities the most conspicuous feature, and in another it was generally diffused over the body. In 2 cases the tongue was greatly invaded, and in many others it was more or less affected. In 5 cases the evidences of tubercular deposit were limited to the face and ears; in the rest the extremities and other parts of the body participated to a greater or less extent.

The distribution of the deposit on the face, ears, etc., varied greatly in different instances, and the manner in which it was deposited also exhibited considerable variety. In some cases it was diffused, causing general thickening over wide areas; in others it occurred as isolated, sharply-defined, prominent nodules. The sites of chief deposit were those well known as those specially selected in the disease—the malar prominences, eyebrows, nose and ears. In some cases there were prominent tubercles on the upper eyelids, which added considerably to the deformity due to the general thickening of the tissues and the coarse deep furrows on the forehead between the various areas of deposit. The deposit, when affecting the nose, generally appeared to take origin around three centres, affecting the tip and *alæ* respectively. This caused the formation of irregular lobes, and, when the condition was advanced, ended in causing the nose to present a distinct tri-lobed extremity. The lobes of the ears were very greatly affected, becoming thickened, nodular and pendulous, whilst smaller masses of deposit caused irregular roughening and thickening along the rims. The appearances present in advanced cases are very well shown in Plate XXXI, Fig. 1, where the pendulous nodulated ears, the coarse folds on the forehead, the prominent tubercles on the upper eyelids,

depressing them and almost closing the eyes, the general thickening of the cheeks, and the tri-lobed condition of the nose are all clearly visible.

Where tubercular deposits occurred in the extremities it was often difficult to determine to what extent they were due to deposit in the course of the cutaneous nerves, and how far to material actually occupying the tissue of the skin itself. Many of them were, however, so superficial, that if in any way specially connected with the nerves, it could only have been with their terminal filaments.

Anæsthesia.—In only one case did this appear to be entirely absent. This was an acute case of short duration; the patient was a boy of 10, and the disease had only lasted for one year. In the other cases the areas occupied by deposit were more or less completely anæsthetic, but general anæsthesia of entire regions was much less common, complete, or extensive than in the form of the disease first described. When present, it showed the same preference for the extremities and for the extensor rather than the flexor surfaces of the affected limbs, as was previously noted in reference to anæsthetic leprosy (p. 460).

In one case only was pain complained of. It extended across the dorsum of the right foot from the fourth toe, which was distorted and swollen, to the inner side of the ankle joint.

Except over the sites of deposit, the skin of the patients as a rule presented no abnormal appearances. In 2 cases a scaly eruption was present, which in 1 covered the extremities and the lower portion of the trunk, and in the other was situated over the ankle joints. In 5 cases there were open ulcers on the feet or hands, in 1 there was also a large open ulcerating surface on the right cheek (Plate XXXI, Fig. 2), and in another the tongue was ulcerated. In 5 cases the extremities were quite unaffected by ulceration, distortion, or absorptive changes of any kind; in the remaining 7 there was more or less distortion or other evidence of a leprous affection.

The voice was affected in 10 out of the 12 cases. Of the remaining 2, one patient was dumb, the other was the boy previously mentioned as presenting no anæsthetic symptoms. The affection of the voice was probably due to tubercular deposit about the larynx, and was no doubt considerably influenced by the condition of the nose, which was sunken in 5 cases, and in others appeared to be so, due to the thickening and prominence of surrounding parts.

The ages of the patients ranged from 10 to 39 years, with an average of 27 years. The earliest date of attack was 9 years, the latest 30. Taking the 11 cases in regard to which information as to age could be obtained, 1 was attacked under 10 years of age, 6 between 10 and 20, 3 between 20 and 30, and 1 at 30. The average date of attack for the 11 cases is 18·90 years.

The duration of the disease varied from 1 to 14 years with an average of 8·27 for all cases. Of the cases 8 had lasted for a period of under 10 years, and 3 for periods between 10 and 20 years.

In 3, or 25 per cent. of the cases, there was a history of the occurrence of

leprosy in the patient's family; in the remaining 8 the existence of disease among any relatives was denied. The affected relatives were in one case the father, in the second the mother, and in the third the mother's brother.

In 11 cases a history of the initial symptoms of the disease was obtained. In 7 the occurrence of patches of eruption is stated to have been the first symptom; in 1 cracking of the skin of the heels followed by eruption; in 2, cracking of the skin of the feet; in 1, a similar affection of the skin over the ankle joints; and in 1, generally diffused pain in the joints of the extremities. Here, as in the case of the anæsthetic form of the disease, eruption seems to have been the most common initial symptom.

The blood was examined microscopically in 10 of the 12 cases. In 8 of these the number of white corpuscles present in the specimens was excessive. In some this excess was very strongly marked, and the normal white corpuscles were accompanied by an abundance of smaller bioplastic fragments. In 2 cases, the only abnormal feature present was a soft and adhesive condition of the red corpuscles—a condition which also occurred along with the excess of white corpuscles in one of the other cases.

4.—*Analysis of the Cases in the Asylum affected equally by the Two Forms of Disease*—"Mixed" *Leprosy.*

"*Mixed*" *Leprosy.*—This variety of the disease occurred in 15, or 18·6 per cent. of the total cases. It was in one or two cases a matter of doubt whether cases included under this head should not rather be referred to one or other of the previous categories, but with regard to all the rest there could be no doubt as to the propriety of retaining them in an intermediate class, as the tuberculated and anæsthetic phenomena were so equally balanced, that it was impossible to say which predominated.

From their very nature it necessarily follows that the variety in the symptoms was very great. In some the only feature distinguishing them from purely anæsthetic cases was more or less distinct thickening of the alæ of the nose, or slight deposit about the cheeks and eyebrows, and in one specially doubtful case the tubercles were confined to the feet. The extent of anæsthesia also varied greatly. Special details in regard to those points are unnecessary, as they would in great part consist of repetitions of those previously given in connection with the tuberculated or anæsthetic cases. In 1 case the tongue was anæsthetic, but the sense of taste was partially retained.

In 3 cases the skin was manifestly more or less affected apart from the changes due to the presence of tubercular deposit. In one of these the skin of the face was shrivelled and presented a peculiar dried-up appearance; in another the skin about the knees was shrivelled, in coarse folds, and marked by scars, and in the third there was a white patch on the skin of one of the feet.

In 7 cases active ulceration was present, in 6 of them confined to the extremities, and in 1 affecting the nose. In 3 the toes showed degenerative changes in more or less marked degree, and in 5 there had been more or less complete loss of digits.

In 7 cases the voice was affected, being husky to a greater or less degree, and in 2 the nose was sunken; in neither of these was there any discharge associated with the condition, nor was there any history of syphilis.

The cases consisted of 8 males and 7 females, or 17·3 per cent. and 20·5 per cent. respectively on the total male and female inmates of the Asylum.

The ages of the patients varied from 16 to 54, with an average of 33·8 for the total. The date of attack varied from 3 years to 40 years of age; 5 cases were attacked previous to 10 years of age; 3 between 10 and 20; 2 between 20 and 30; 4 between 30 and 40; 1 at 40. The average age of attack was 20·2 years. The duration of the disease ranged from 5 to 24 years; in 4 cases it was beneath 10 years; in 8, between 10 and 20 years; in 3, between 20 and 30. The average duration was 13·66 years.

In 6 cases, or 40 per cent., there was a history of disease among the patients' relatives. In 1 both parents and four brothers were lepers, in 2 the father was a leper, in 2 the mother, and in 1 a son.

In 14 of the cases a history of the initial symptoms was obtained. In 9 the disease was stated to have begun with eruption over more or less of the surface of the body; in 1 by the appearance of small tubercles, in 1 by the occurrence of a blister over one of the hip joints, in 1 by cracking of the skin of the soles of the feet, in 1 by a similar affection accompanied by thickening of the face, and in 1 by thickening of the ears.

The blood was examined in 13 cases. In 7 it appeared to be quite normal, in 4, the white corpuscles were present in excess; in 1, excess of white corpuscles was associated with an abundance of bioplastic fragments and a soft glutinous condition of the red corpuscles, and in 1 a similar condition of the red corpuscles was the only peculiarity. In 1 case bleeding occurred on the slightest irritation over the anæsthetic areas, and in another blood could only be obtained with difficulty.

5.—*Analysis of cases in the Asylum in which the eruption was the most marked feature*—"Eruptive" *Leprosy.*

Although it is questionable whether this should be separated as a variety from one or other of the previous categories, seeing that the eruption seems rather to constitute a symptom common to the previous classes; there are, at the same time, certain cases in which this symptom is of such marked and persistent character as to justify their separation. Four cases of this kind were met with among the inmates of the Almora Asylum. Of these three were males and one a female.

In 3 of them the symptoms associated with the eruption were of a markedly

anæsthetic nature, whilst in the fourth the anæsthetic was of very limited extent, and the eruption had a peculiar aspect, appearing rather to be due to diffuse tubercular deposits of minute size, varying from mere points to the size of sago-grains, than to an eruption of the nature ordinarily occurring as a symptom of leprosy. In the remaining cases the eruption consisted of irregularly rounded pale-coloured patches, more or less symmetrically distributed (*vide* Plate XXIX), and generally bounded by slightly elevated margins of a faint pinkish hue. The skin over such patches was, as a rule, more or less distinctly anæsthetic, and in one case progressive increase in the degree of anæsthesia could be clearly determined in proceeding from their margins towards the centres.

As previously mentioned, anæsthesia was very extensive in 3 of the cases, affecting the face, the entire upper and lower extremities and portions of the trunk. In the fourth case it was confined to the extremities from the elbows and knees. In none of the cases were there any characteristic tubercular features present.

There were numerous scars along the extensor surface of the right upper extremity in 2 cases, and traces of burns on the hand of a third. The skin at the elbows in one, and over the knees in another, was dry, shrivelled and thrown into coarse folds. Active ulceration existed in 3 cases; there was more or less absorption or loss of digits in all, and in 2 the remaining digits were strongly contracted.

The blood was examined microscopically in 3 out of the 4 cases, and found to be perfectly normal in appearance.

The ages of the patients varied from 15 to 40, with an average of 30·25 years. The earliest age of attack was 8, the latest 31 years; 1 occurred previous to 10 years; 1 between 10 and 20; 1 between 20 and 30; and 1 at 31. The average for all cases was 20·25 years. The duration ranged from 5 to 16 years, that of 2 cases being beneath 10 years, that of the others between 10 and 20. The average was 10 years.

In 1 case the patient's mother and one brother were lepers; in the rest the occurrence of leprosy among relatives was denied.

In 2 cases the disease was said to have begun with the appearance of patches of eruption over the body, in 1 with cracking of the skin of the soles of the feet, and in 1 no history could be obtained.

6.—*Analysis of the features common to all the forms and varieties of Leprosy as observed in the Asylum.*

The foregoing chapters constitute a summary of the symptoms and history obtained by a systematic examination of the various forms of leprosy in the Asylum, and we next proceed to consider some questions common to all of them as varieties of one disease.

The following table shows the age of attack of all cases in which information could be obtained on the point:—

TABLE XI.

Showing the Age of Attack in all the forms of Leprosy.

Males.				Females.			
Number of cases.	Age in years.	Number of cases.	Age in years.	Number of cases.	Age in years.	Number of cases.	Age in years.
5	8	3	28	1	3	2	20
2	9	3	30	1	8	3	22
2	10	2	31	3	9	4	25
1	11	1	32	1	11	5	30
3	12	1	33	1	12	1	31
1	13	1	36	1	13	1	32
1	14	1	38	2	16	1	33
2	16	3	40	1	17	1	37
4	18	1	47	1	18	1	58
3	24	1	50	1	19	1	60
2	25	1	58				
1	26						

The age of attack among the 79 cases varied from 3 to 60 years, the average being 23·73. The average age for males was 23·68, that for females 23·79.

The following statement shows the average age of attack in the four classes of cases compared with one another, and with the average for the total:—

TABLE XII.

Average Age of Attack in each of the several forms of Leprosy.

Total.	Anæsthetic cases.	Tubercular cases.	Mixed cases.	Eruptive cases.
23·73 years.	26·18 years.	18·90 years.	20·2 years.	20·25 years.

The next statement shows ages of attacks according to decennial periods:—

TABLE XIII.

Occurrence of Attack in Decennial Periods.

Decennial Periods.	Total Lepers.	Anæsthetic cases.	Tubercular cases.	Mixed cases.	Eruptive cases.
0 to 10 years ...	12	5	1	5	1
10 to 20 ,, ...	22	12	6	3	1
20 to 30 ,, ...	18	12	3	2	1
30 to 40 ,, ...	19	13	1	4	1
40 to 50 ,, ...	4	3	0	1	0
50 to 60 ,, ...	3	3	0	0	0
60 to 70 ,, ...	1	1			

The above figures, although obtained from a comparatively small number of cases, are generally in accordance with what has been recorded by other writers. The

averages show that the average date of attack was latest in pure anæsthetic cases, earliest in those in which tubercular symptoms predominated, and, as might have been expected, intermediate for the mixed and eruptive cases. The climax of anæsthetic cases occurred in the decennial period between thirty and forty, but the number of cases for the two preceding periods was almost equal to it, whilst that in the two following ones is less than a quarter as great, and is followed by the minimum in the next. In the tuberculated form, on the other hand, the maximum occurred in the second decennial period; the number furnished by the third is diminished by one-half, and is followed by the minimum in the fourth period. The mixed cases are more equally distributed, but the numbers show two maxima, one in the first, the other in the fourth period, probably indicating a division of the cases into two sections, one in which the anæsthetic, the other in which the tubercular element predominated. The four cases of eruptive leprosy are equally distributed over the first four decennial periods.

There is one point in which these figures regarding the age of attack do not correspond with those derived from some other sources, and this is that, in regard to average age of attack compared with sex, there is no evidence of a tendency to earlier attack in females than males. On the contrary, the average age for the females is slightly in excess of that for the males. That this average is not fallacious, but really corresponded with a greater tendency to early attack among the males, is shown by the following statement of numbers of attacks in the sexes according to decennial periods:—

TABLE XIV.

Age of Attack in the Males and Females according to Decennial Periods.

Decennial Periods.	Percentage of Attacks at the different Periods.	
	Male Lepers.	Female Lepers.
0 to 10 years	15·5	14·7
10 „ 20 „	31·1	23·5
20 „ 30 „	20·0	26·4
30 „ 40 „	20·0	29·4
40 „ 50 „	8·8	0·0
50 „ 60 „	4·4	2·9
60 „ 70 „	0·0	2·9

The phenomenon in the present instance is no doubt in great measure due to the differences in the percentage of males and females suffering from anæsthetic and tuberculated leprosy, for the percentage of females for the former was 70·5, and that of the males was only 55·5, whilst the conditions were reversed in regard to tubercular leprosy, 20·0 per cent. of the males and only 5·8 per cent. of the females suffering from it. The average age of attack for females in the anæsthetic

form was less than that for males, being 24·8 compared with 27·4, which tends to the same conclusion.

The next table shows the duration of disease :—

TABLE XV.

Duration of Disease.

Males.				Females.			
Number of cases.	Duration in years.	Number of cases.	Duration in years.	Number of cases.	Duration in years.	Number of cases.	Duration in years.
3	1	3	15	2	2	1	17
1	2	4	16	1	4	1	18
3	6	2	17	4	5	3	20
3	7	1	18	1	6	1	22
1	8	1	19	2	7	1	23
3	9	2	20	3	8	3	24
3	10	1	21	3	9	3	25
6	12	3	23	2	10	1	27
1	13	1	32	1	15	1	29
2	14	1	40				

The shortest period of duration was one year, the longest forty ; the average for all cases was 13·69 years ; the average duration for males was 13·66 and that for females 13·73 years.

The following are the average periods of duration in each form of disease compared with one another and with the total average :—

TABLE XVI.

Average Duration of the different forms of the Disease.

AVERAGE DURATION OF THE DISEASE IN YEARS.

Total Lepers.	Anæsthetic cases.	Tubercular cases.	Mixed cases.	Eruptive cases.
13·69	15·22	8·27	13·66	10·0

The following table shows periods of duration according to decennial periods : -

TABLE XVII.

Duration of the several forms of Leprosy in Decennial Periods.

Decennial periods.	Total cases.	Anæsthetic cases.	Tubercular cases.	Mixed cases.	Eruptive cases.
0 to 10 years	30	16	8	4	2
10 „ 20 „	28	15	3	8	2
20 „ 30 „	19	16	0	3	0
30 „ 40 „	1	1	0	0	0
40 „ 50 „	1	1	0	0	0

With regard to the question of duration, these figures are of course very insufficient, as they do not show duration to the termination of the disease, but only to time of examination. Unfortunately, however, they constitute all the information which is at present attainable on the subject from the Almora Asylum. It is only quite recently that information regarding the date of attack has been registered, or that the cases have been discriminated according to the form of disease, so that nothing can be obtained from the past history of the institution. In the failure, then, of better evidence on the subject, we are driven to take the length of residence in the Asylum. There is no evidence to show that tubercular leprosy has latterly increased in frequency as compared with the anæsthetic form of the disease, so as to have caused the entrance of a disproportionate number of cases into the Asylum within recent years, and none that there is a tendency among the sufferers from any special form of the disease to desert the institution, so that the average duration of cases at present in the Asylum probably represents the actual relations existing in this respect between the various forms of the disease. The want of previous records is more likely to give origin to serious fallacy in attempting to calculate the relative frequency of the occurrence of the different forms of disease, for those of the latter whose duration is longest are likely to furnish an accumulation of cases of survival giving rise to an appearance of relative prevalence greater than actually exists.

The figures as they stand advance evidence of their correctness by agreeing with those obtained in other places in showing the much shorter duration of the tubercular as compared with the anæsthetic form.

In regard to the case with a duration of forty years, it was very difficult to determine whether the patient was, at the time of examination, suffering from actual disease or only from the effects of that which had formerly been present; save slight ulceration of the soles of the feet, there were no symptoms but those ascribable to former nervous injury and muscular atrophy. The short duration of the eruptive cases corresponds with the initial character of the symptom as a manifestation of the disease.

7.—*The evidence which the Asylum affords on Contagion.*

The theory that leprosy is a contagious disease has in recent years been revived in some quarters, and a careful inquiry was therefore made for any evidence bearing on the point. The means which most naturally suggested itself for doing so was an examination of the history of all the married lepers, for were the result of this to show that the wives or husbands, as the case might be, of lepers, suffer frequently from the disease, this would be some evidence in favour of contagion, except in cases in which the marriage was demonstrated to be one contracted between lepers, or in which there was a family history of leprosy for both the contracting parties. Even with these limitations, evidence of this nature collected in a district in which

leprosy is endemic would be by no means conclusive, as the possibility of remote hereditary taint or even of *de novo* development of the disease would remain. In the present instance, as will be seen, we are fortunately not obliged to enter into such considerations.

The following statement shows the numbers of male and female married lepers and of the condition of their husbands and wives:—

TABLE XVIII.

Condition of Wives and Husbands of Married Lepers.

MALES.					FEMALES.				
No.	State of Wife. Alive or dead.	Leprous.	Non-Leprous.	Remarks.	No.	State of Husband. Alive or dead.	Leprous.	Non-Leprous.	Remarks.
1	Alive	0	1		1	Alive	0	1	
2	„	0	1		2	„	0	1	Married as a child.
3	„	0	1		3	Dead	0	1	„ „
4	„	0	1		4	Alive	0	1	
5	„	1	0	Married to a leper-woman in Asylum.	5	„	0	1	
6	Dead	1	...	„ „	6	2. 1st alive, 2nd dead.	1	1	2nd marriage in Asylum.
7	Alive	1	...		7	2. 1st alive, 2nd dead.	1	1	„ „
8	„	0	1						
9	„	0	1		8	2. Both alive...	1	1	„ „
10	„	0	1		9	Dead	0	1	
11	„	1	0	„ „	10	1 alive	0	1	
12	„	0	1		11	Alive	1	0	Married in Asylum.
13	1 alive, 2 dead	0	3	Thrice married, all wives non-leprous.	12	2. 1st alive, 2nd dead.	1	1	2nd marriage in Asylum.
14	1 ditto... ...	0	1		13	2 alive	1	1	„ „
15	1 alive, 1 dead	1	1	1st wife alive, 2nd marriage in Asylum.	14	„	1	1	„ „
16	Alive	0	1		15	Alive	0	1	
17	Dead	0	1		16	Dead	1	0	
18	Alive	0	1		17	„	0	1	
19	„	1	0	Married in Asylum.	18	Alive	0	1	
20	„	1	0	„ „	19	„	0	1	
21	Dead	0	1		20	„	0	1	
22	Alive	0	1		21	Dead	0	1	
23	„	0	1		22	2 alive	1	1	„ „
24	„	0	1		23	Dead	0	1	
25	„	1	0	„ „	24	2 alive	1	1	„ „
					25	Dead	0	1	
					26	Alive	0	1	
					27	Dead	0	1	
Total 25		8	20	The eight lepers were married in Asylum.	27		10	25	Nine out of the ten leprous husbands were married in Asylum.

Of the 52 lepers married, 18 had leprous wives or husbands, but as 17 of these marriages were contracted between lepers in the Asylum, there remains only one case in which the possibility of contagion is to be considered, and certainly this

isolated instance cannot be regarded as affording any trustworthy evidence, as in an endemic area the possibility of the occasional occurrence of marriages between predisposed parties must always exist.

The history of the Asylum furnishes no other evidence in favour of contagion; there is no evidence of attendants or others employed about the institution or of those in any way connected with it having suffered from the discharge of their duties in any way. *

8.—*The evidence which the histories of the inmates afford on the influence of heredity.*

We next come to the question of heredity of the disease. The inmates of this Asylum belonging to more or less localised hill communities offer greater facilities for the elucidation of this subject than the inmates of similar asylums in the plains, seeing that the former have usually more definite information than the latter concerning their present and ancestral relatives. On this account, therefore, the information which we have obtained from these people regarding the influence of heredity in the propagation of leprosy may, we think, be considered as of more than ordinary trustworthiness.

Table XIX shows the number of lepers with leprous relatives, with the degree of relationship in each instance.

We thus obtain unequivocal information that of the eighty lepers in the Asylum at present, 28, or 35 per cent., had one or more leprous relatives. This percentage gives a proportion 140 times greater than the percentage of lepers to the total population of the district, and allowing the fullest play to the possible influence of similarity of external conditions, points to the distribution of the disease by families and therefore to hereditary predisposition. The circumstance that in 2 of the 4 cases in which both parents were leprous, the total number of leprous relatives was greater than in any of the others, and in fact furnished nearly a fourth of the total of leprous relatives for the 28 cases, also supports this conclusion.

It should be borne in mind, moreover, that many of the inmates had not for years past learnt anything of the individual histories of the various members of their families, so that this circumstance (in addition to the paucity of precise information regarding the particular ailments of distant relatives, common to all families) tends to show that even this high ratio under-states the actual proportion of leprous kindred.

* Among the cases reported to the College of Physicians in support of the contagious nature of the disease there is one quoted on the authority of a Native Sub-Assistant Surgeon, in which it is stated that two men, who acted as durwans, *i.e.*, gate-keepers, at the Almora Asylum, were attacked by leprosy whilst so employed. ["Report on Leprosy by the Royal College of Physicians;" London, 1867, page 141.]

On referring to the Superintendent of the Institution, the Rev. Mr. Budden, for information on the point, we have been informed that the Sub-Assistant Surgeon in question "knew nothing about the Asylum; and the statement," writes Mr. Budden, "has no foundation whatever. Nothing of the kind reported has ever occurred in the Asylum since I took charge of it in 1851."

TABLE XIX.

Lepers with Leprous Relatives.

Number.	NATURE OF RELATIONSHIP.								
	Parents.			Brothers.	Sisters.	Sons.	Daughters.	Other Relations.	Total Relations affected with Leprosy.
	Both.	Father.	Mother.						
1	1	...	...	4	...	...	...	... ...	6
2	1	...	...	...	...	...	...	... ...	2
3	1	...	...	...	...	...	...	... ...	2
4	1	...	...	3	...	...	...	... ...	5
5	...	1	...	...	...	...	...	... ...	1
6	...	1	...	...	...	...	...	... ...	1
7	...	1	...	...	...	...	...	... ...	1
8	...	...	1	...	1	...	...	... ...	2
9	...	...	1	...	...	...	...	... ...	1
10	...	...	1	...	...	...	...	... ...	1
11	...	...	1	...	...	...	...	... ...	1
12	...	...	1	...	...	...	...	... ...	1
13	...	...	1	1	...	...	...	Mother's brother ...	3
14	...	...	1	...	...	...	...	... ...	1
15	...	...	1	1	...	...	...	Mother's brother ...	3
16	...	...	1	...	...	...	...	... ...	1
17	...	...	1	...	...	...	...	... ...	1
18	...	...	...	...	...	...	...	Father's brother ...	1
19	...	...	...	...	...	...	...	,, ,, ...	1
20	...	...	...	...	...	...	...	Mother's brother ...	1
21	...	...	...	...	...	...	...	Father's father... ...	1
22	...	...	...	...	...	...	...	Sister's child	1
23	...	...	...	1	...	...	...	... ...	1
24	...	...	...	1	...	...	...	... ...	1
25	...	...	...	1	...	...	...	... ...	1
26	...	...	...	1	1	...	...	... ...	2
27	...	...	...	...	...	4	...	... ...	4
28	...	...	...	...	...	1	...	... ...	1
Total ... 28	4	3	10	13	2	5	...	7	48

The figures in the table seem to indicate that there is a strongly marked tendency in the disease to follow the female line of descent. Of the 17 persons born of leprous parents, both parents were affected in 4 instances. The father alone was leprous in 3, whereas the mother alone was leprous in no less than 10—giving percentages of 23·5, 17·6, and 58·8 respectively on the total 17 cases. Taking all cases in which parents or parents' relatives are affected, we find 10 cases in which the father or father's relatives are leprous, and 17 in which the disease was present on the maternal side.

Nineteen of the 28 cases with leprous relatives were males and 9 females. Of the former there were 9 cases in which the father or father's relatives were affected, 12 in which the mother or mother's relatives, 7 cases in which brothers', and 2 cases in which a sister or sister's relatives were leprous: among the latter, the father was affected in 1 instance, the mother in 5, a brother and sister in 1 and a son in 1; among the males, there were 15 cases in which male

relatives and 10 in which female relatives were affected. Among the female lepers, on the other hand, there were 4 cases in which male and 6 in which female relatives were affected. The above figures are too limited in amount to form definite conclusions from, but they suggest the possibility of the existence of a tendency in the disease to adhere by preference to one or other sex in a leprous family.

The special conditions favouring the development of the disease in the predisposed is a matter for further inquiry. The data attainable from the examination of the inmates of the Asylum did not throw much light on the point. The disease, so far as can be judged from these cases, would not appear to be specially prevalent among any particular class of the community, as is shown in the following statement:—

TABLE XX.

Leprosy in relation to Caste.

Caste.	No. of cases in the Asylum.
Dome	39
Rájpút	30
Brahman	1
Buniyah	1
Christian	1

As the inhabitants of Kumaon virtually consist of two classes only—Rájpúts and Domes, the former representing an Aryan population, the latter the aboriginal people—whilst other classes are only very sparingly represented, the evidence, such as it is, is in favour of impartial distribution of the disease.

The question of the influence of occupation in connection with the etiology of leprosy will be considered on a future occasion.

9.—*The number of Children born in the Asylum, in connection with the statistics of the disease in the District.*

In connection with the question of heredity, and more especially in regard to the risk of an increase of the leper population of a district, the number and

* According to the Census Report of the North-West Provinces (1873) the composition of the Hindu population of the district of Kumaon in regard to caste is as follows:—

Brahmans (*a*) 25·4; Rájpúts 42·6; Buniyahs 0·8; other Hindu castes 31·2 = 100.

(*a*) "Among the lower ranks of Brahmans, great latitude is taken in regard to labour, food, etc., and their claim to the distinction of that caste is, in consequence, little recognised; the mass of the labouring population from similar causes have still less pretension to the designation of Rájpúts which they assume. The Domes are, of course, outcasts, and to them are left the whole of the inferior trades,—those of carpenters, masons, blacksmiths, miners, musicians, etc.,—and by them also are performed the most menial offices."—"Statistical Sketch of Kumaon," by G. W. TRAIL.—*Asiatic Researches*, Vol. XVI.

condition of the children of the lepers in the Asylum was carefully inquired into. The following table is a summary of the information thus obtained :—

TABLE XXI.

Table showing the condition of the Children (101) *of* 51 *of the leprous inmates of the Asylum.*

No. of leper-parent.	Males.		No. of leper-parent.	Females.	
	Number of children.	Condition of children.		Number of children.	Condition of children.
1	1	Healthy ; alive.	1	1	Healthy.
2	1	,, ,,	2	0	
3	0		3	0	
4	2	1 dead.	4	0	
5	2	Alive ; healthy. Born in Asylum.	5	0	
6	2	1 dead ; 1 alive, healthy. By marriage in Asylum.	6	2	Dead. By marriage at home.
7	0		7	1	Healthy. Born in Asylum.
8	1	Alive ; healthy.	8	2	Healthy ; 1 born in Asylum, 1 at home.
9	3	,, ,,	9	6	2 dead, 4 healthy.
10	1	Dead.	10	7	5 dead ; all born at home.
11	0		11	0	1 dead ; all born at home ; 4 healthy.
12	3	Alive ; healthy.	12	5	Healthy.
13	0		13	0	7 dead.
14	2	,, ,,	14	1	4 leprous. Husband a leper.
15	1	Dead.	15	8	Healthy.
16	4	Healthy.	16	9	4 dead, 4 healthy.
17	1	,,	17	2	1 ,, 1 ,,
18	1	,,	18	8	1 ,, 4 ,,
19	0		19	2	3 ,, 2 ,,
20	0		20	5	Dead.
21	0		21	5	Healthy.
22	0		22	3	
23	1	Healthy.	23	1	
24	1	,,	24	0	
25	0		25	2	1 dead, 1 alive ; healthy.
			26	4	Healthy.
			27	2	1 leprous.
Total 25	27	23 alive—0 leprous, 4 dead.	Total 27	76	46 alive—5 leprous, 30 dead.

From this table we learn that the 52 married lepers in the Asylum have produced a total of 101 children. The numbers as stated in the table are 103, but a deduction of two has to be made, as two are entered in both columns, being the offspring of marriages in the Asylum. Of these 69 are alive. These 52 lepers have contributed a permanent addition of 17, or 32·6 per cent., to the population under review ; for 52 of the children must be deducted as merely replacing their parents, so that the possible increase of lepers due to them is 17. It is, however, extremely unlikely that all the children should live, or that all that live should turn out leprous, so that the

probability of actual increase is almost *nil*. The foregoing table shows, that the mortality among the offspring of lepers is very high. 39·4 per cent. of the children of female lepers is seen to have succumbed at an early age, or 33·6 per cent. when the mortality of the juvenile offspring of both the male and the female lepers is estimated; it is therefore probable that a considerable proportion of those still living will be short-lived. Up to the present time only 5 cases of leprosy have manifested themselves among the children, and of these 1 is dead, so that only 4 of the leper parents have been substituted as yet by leper children, leaving an excess of 48 to be accounted for. The proportion of lepers among these children is very small, which is probably due to the fact that many of them are still beneath the age at which the disease usually manifests itself. At the same time many others are adults, manifest no indications of leprosy, are married, and have apparently healthy children.

Our figures seem to suggest that another fact should be taken into consideration in endeavouring to estimate the risk of increase in the leper population, and this is the very small number of children produced by the majority of the leprous parents.

In connection with this point, it is very remarkable to observe how much smaller a number of children is to be credited to the male than to the female lepers, the absolute numbers being 27 and 76 respectively, and the averages of children to families being 1·08 in one case and 2·8 in the other, or after deducting those cases in which both parents were lepers, 1·0 and 2·8 respectively. A third of the male married lepers have no offspring. So far as the evidence goes, the total number contributed to the population by the female lepers is about 70 per cent. in excess of that contributed by the males. As a set-off to this, however, the table shows that about 24 per cent. more of the children born to female lepers died than of the children born to male lepers.

If the figures really mean the actual occurrence of larger families where the female than where the male parent is leprous, several explanations of the phenomenon suggest themselves. It appears probable that the age at which the disease is developed exerts an important influence. It cannot, however, act directly to any great extent, for, as a general rule, we know that the disease tends to be developed as soon, if not sooner, in the female than in the male. It is the inequality in the age of the parents which appears likely to tell on the number of children. In this country there is often such great disparity between the ages of men and their wives that, allowing the age for the manifestation of disease to be practically alike for both, the females have a much longer time previous to its advent in which to produce children than the males have.

That the age of manifestation of the disease really does influence the numbers of children in one way or other is supported by the facts recorded in the following table, which shows the ages at which the parents became leprous and the numbers

of children in the family. The cases of leper-marriages in the Asylum have been excluded, as well as one in which the age of attack in the parent was unknown:—

TABLE XXII.

Age of Attack and Number of Children of Married Lepers.

Males.				Females.			
Age of attack (years).	No. of children.	Age of attack (years).	No. of children.	Age of attack (years).	No. of children.	Age of attack (years).	No. of children.
24	1	32	2	16	0	30	8
25	1	38	0	19	0	30	8
25	0	40	0	22	0	30	5
26	1	40	0	22	0	30	1
28	4	40	3	22	1	31	4
30	1	47	1	25	2	32	2
30	1	50	3	25	2	35	2
31	2	58	1	30	5	58	5
						60	9

The chief interest connected with these figures lies in the fact that they appear to supply a means of, in a great degree, explaining, for this country at all events, the apparent preference of the disease to follow the female line of descent. The tendency to follow the female line is possibly, however, also, partially due in many districts, such as Kumaon, to the greater frequency of the tuberculated form of leprosy among males than females—that form usually appearing at an earlier age than the anæsthetic.

Returning to the question of increase in the leper population, we must, in order to arrive at any definite conclusion, endeavour to obtain further information as to the number of children born in other leper families and the proportion of them who become leprous. The only data at our disposal in the present instance consist of those furnished by the family history of those of the lepers whose parents were leprous. Seventeen such cases exist, and the particulars of these are embodied in Table XXIII.

We have here 17 leprous families containing 21 leprous parents giving 68 children, of whom 27 are leprous. This is a larger proportion of children, and a very much larger proportion of leprous children, than is given by the other set of cases (Table XXI), where, reckoning all those cases in which those married are both lepers, and allowing for the cases appearing in both columns, we have 52 lepers with 101 children, and 5 leprous children. The numerical data before us, illustrating the extent to which a manifestly leprous parent may determine the predisposition to the disease in his own immediate offspring, may be thus summarised:—To 79 leprous persons 169 children were born; 34 of these are known to have died prematurely. Among the remaining 135 children leprosy has already manifested itself in 32 cases, or in 23·7 per cent., nearly one-fourth of the total number. This, too,

TABLE XXIII.

Table showing the number of Children and of Leprous Children in 17 *Families in which one or both Parents were leprous.*

No.	Parents.	No. of Children.	No. of Leprous Children.
1	Both.	10	5
2	,,	3	1
3	,,	4	1
4	,,	7	4
5	Father.	2	1
6	,,	5	1
7	,,	5	1
8	Mother.	3	2
9	,,	2	2
10	,,	3	2
11	,,	4	1
12	,,	2	1
13	,,	2	1
14	,,	4	1
15	,,	2	1
16	,,	6	1
17	,,	4	1
17	21	68	27

doubtless materially understates the number of cases of the disease which may ultimately occur among them, as the majority of the children are below the average age at which the disease manifests itself. Nevertheless, when we take into consideration the comparatively small families which lepers have and the high rate of mortality among the children, it is not probable that the contribution to the leprous community will in the present instance do more than replace the numbers of the present generation. Indeed, the figures which are before us may be worked out to show an actual decrease, but we consider the number of cases, with regard to which we possess accurate information, too small to form the ground of practical generalisations.

Taking all the information attainable from these figures, there appears, therefore, to be no great risk of increase to the leper population of Kumaon as far as the disease is dependent on heredity for its multiplication.

Since the year 1866, from which period only trustworthy data are available from the registers of the Asylum, 7 births have occurred in the institution. The total number of inmates of the Asylum during the period have been 114 males and 61 females; and as until the present year there has been no attempt at separation of the sexes beyond giving them separate sleeping compartments, and no supervision specially designed with the object of keeping them apart, the very small ratio of births is very remarkable, and must mainly, at all events, be credited to the influence of the disease. Between 1866 and 1871, moreover, 31 marriages were contracted

between male and female lepers under the sanction of those in charge of the institution. In 29 of these marriages no children were produced; 2 were fruitful to the extent of two children each.

In connection with this subject, a very interesting experiment is now in progress at Almora. There are at present in the orphanage 12 children of lepers now or formerly inmates of the Asylum. The total number of such children who have been admitted into the orphanage is 14, but of these 1 has died, and another, a girl of twenty-two, has now left the orphanage, is married and has children—healthy to all appearances. Of the 12 remaining, 7 were born in the Asylum of two leprous parents, 5, the offspring of one leprous and one healthy parent, were born in the villages to which their parents belonged. Their ages range from 19 to 5 years; their health and general condition is excellent, and as yet they show no signs of leprosy. The experiment is as yet imperfect, but it is capable of affording very valuable information if the future history of the children be carefully noted. They have been removed from the surroundings under which the disease manifested itself in their parents, have been well fed and carefully attended to, and their subsequent history cannot but throw light on the extent to which the influence of heredity can exert itself, or may be modified and kept in abeyance by ameliorated conditions of life.

10.—*Practical suggestions.*

So far as our information goes, it appears then, that, even allowing for a certain proportion of imported cases, any risk of rapid increase in the prevalence of leprosy in Kumaon is not to be apprehended. We have no satisfactory evidence of contagion and none of a rapid *increase* of cases due to hereditary influences. Whilst, however, the prevalence of the disease remains as high as it is, there is ample reason for determined effort to ascertain by what laws this prevalence is regulated and by what practical measures it may be diminished.

The means for affecting this can hardly be looked for in attempts at forcible repression of the disease, such as the compulsory imprisonment of lepers in Asylums. Quite apart from the objections founded on the tyranny involved in any such measures, there are other serious and almost insurmountable difficulties in carrying them effectually out. It would not be sufficient merely to confine those suffering from developed disease, but all those who might in any degree be supposed to be hereditarily disposed towards it, would have also to be secured. It would, in truth, be even more important to secure the latter, for, from the present evidence, there appears to be only a very small number of children born to confirmed lepers. But had all those predisposed to be secured, how and by whom could the existence of predisposition be determined? In the case of hereditary predisposition, it is quite uncertain for how long—for how many generations, the disposition may be transmitted without giving any ostensible sign of its presence, but capable under certain circum-

stances of giving origin to the development of disease. How, then, is the absence or disappearance of predisposition to be determined?

That Asylums, properly so called, are very useful and desirable institutions in districts where chronic diseases like leprosy prevail, is just as true as that prisons ought not to be substituted for them. By their means a shelter is secured for the patients where they may be benefited by treatment, and where they, in many cases, are certainly saved from much suffering; where the phenomena of disease may be studied, and the effects of curative means tested. By their means, moreover, the existence of a large amount of miserable beggary in a district may be avoided. Such institutions are, beyond doubt, calculated to do very great good, and deserve all support and encouragement so long as such support does not relieve the relatives of the diseased from the performance of their duties to the sick—so long as their existence does not afford an encouragement to people to profit by the misfortune of their relatives at the expense of the community.

Such have been the results of our investigation during the present year. They have, at all events, served to clear the way for further work, and to point out the direction to be followed in more detailed local inquiry.*

SUMMARY.

A BRIEF recapitulation of the principal points to which reference has been made in this our first report regarding leprosy may be of use to such readers as have not sufficient time to study the question in detail. It must, however, be premised that any digest relating to such an obscure subject is necessarily attended with more risk

* The results of our inquiries hitherto regarding leprosy correspond closely with a similar inquiry very recently carried out in Sicily by Dr. Profeta. We have already, in an earlier part of this Report, referred to this investigation, but as we have not seen any account of these researches in any English journal, we subjoin a short translated abstract of Dr. Profeta's paper. Since the year 1867, the author has collected information regarding 114 cases of leprosy in Sicily—80 men and 34 women. In three-fourths of the cases he was able to trace the disease to inheritance—in a few instances he had to trace the malady in relatives four times removed. In no instance was there any evidence of contagion, although 22 of the lepers had lived with their families for many years.

Children who had been suckled by leprous women had not, apparently, been infected thereby, nor had re-vaccination with lymph obtained from leprous persons been shown to transmit the disease. (It is not mentioned how long a period has since elapsed.) The inference that leprosy may be dependent in some way on a fish diet is not (as mentioned in a previous page) supported by experience in Sicily, seeing that the disease prevails among the inland population to a greater extent than along the coast; nor do poverty, want and filth seem to exercise important influence as factors, for the disease is even more prevalent among the well-to-do classes; and, least of all, could the disease be attributed to malarial influences. So that the author has come to the conclusion that heredity is the only ascertained etiological agent in its propagation—"So dass in der That nur die Erblichkeit als ätiologisches Moment übrig bleibt."

Of the 114 persons, 9 were affected at ages ranging from 7 to 10 years; 26, at 11 to 20 years; 39, at 21 to 30 years; 22, at 31 to 40 years; 11, at 41 to 50 years; and in 7 cases the disease was not manifested until the persons had reached ages ranging from 51 to 65 years. The duration of the disease, taking the average of all the cases, was 13 years, the minimum being 3 years and the maximum 40. Both the tuberculated and anæsthetic forms of leprosy occur in Sicily, the latter form being somewhat more common than the former.—Virchow and Hirsch's *Jahresbericht über die gesammten Medicin.*—X. Jahrgang, Band I. Abth. 2. S. 431: Berlin, 1876.

of misinterpretation than a detailed report where all the qualifying circumstances of any set of deductions can be produced.

It will have been seen that although leprosy was known to prevail in Hindostan many centuries before the Christian era, comparatively little was known regarding its precise localisation in the different provinces until the general census of 1872 was taken. Not only was the comparative prevalence of the disease in various districts all over British India ascertained at that period, but the possibility of attaining to something approaching to a fair estimate of the aggregate leprous population of the country also became practicable. According to these census returns, there are some 99,000 lepers in the territories under British rule, yielding a proportion of 54 lepers to every 100,000 of the entire population, or (taking the actual figures in the first Table) 1 leper to every 1,845 persons. Of the aggregate number about one-eighth is contributed by certain districts, each of not less than 100,000 in population, furnishing a ratio nearly five times higher than the average ratio for the whole of India. In these districts there is a leper to every 384 persons instead of to 1,845. Should these latter data be verified on more close observation, an important step will have been made towards solving the difficulty of dealing with the question in a practical manner, as such a phenomenon must depend either on peculiar local or hereditary conditions.

One of these abnormally affected localities forms the subject of a special report on this occasion, *viz.*, the district of Kumaon. Roughly speaking, it contains 1,000 lepers. This yields a proportion equivalent to something over 250 per 100,000 of the population, or, calculating on the actual figures of the estimate, 1 leper to about every 388 individuals (vide Table V, page 449). With the object of mitigating the sufferings of at least a portion of this unfortunate class, the Commissioner, Sir Henry Ramsay, has founded an asylum at Almora with accommodation for over a hundred lepers.

The inmates of this Asylum formed the subject of a series of clinical observations, the details of which are recorded in the foregoing pages.

Eighty lepers were subjected to the closest scrutiny ; 49 proved to be cases in which anæsthesia presented the most prominent feature; 12 in which the presence of tubercles in the skin was the most marked peculiarity; in 15 cases the two former conditions were so equally evident that they were classified as "mixed;" and in 4 cases an eruption formed the most pronounced symptom. The ratios which these yield agree generally with the proportion in which the different varieties of the disease have been observed to occur in other countries .

The average age at which the onset of the disease was observed was found to be between 23 and 24 years; even the decimals obtained by calculating averages in the case of male and female lepers were found to be almost identical. There was, however, a range of from 3 years to 60. The average duration of the disease was nearly 14 years. The form in which anæsthesia was the prevailing feature was the most chronic, the average duration of the "tuberculated" cases being shorter by nearly six years.

The history of the Asylum gives no support to the doctrine that leprosy is a contagious disease, but strong evidence to the contrary. The reverse has been stated with regard to the history of the Asylum, but it will have been seen, from the information elicited, that not the slightest foundation existed for such a statement.

But with reference to the probable influence of heredity in the propagation of leprosy, the facts elicited, and which may, we believe, be accepted as trustworthy, give forth no uncertain sound. There can, we think, be no very substantial argument adduced in the face of the figures which have been collected in connection with this Asylum alone to contra-indicate the inference that hereditary taint exercises a most important influence in the transmission of the pest.

Taking into consideration, therefore, the prominent part undoubtedly played by heredity, and the fact that the disease but seldom manifests itself until after puberty, it is evident that any attempt at "stamping it out" by the compulsory segregation of leprous persons would prove wholly impracticable; for, as mentioned in the last chapter, it would not only be necessary to segregate those suffering from developed disease, but also those hereditarily disposed to it. How, and by whom, could the predisposition be determined? It would, indeed, be even more important to secure the latter class and such persons as are only manifestly affected to a slight extent; for it would appear that persons of this description furnish by far the greater portion of the children who are, so to speak, potentially leprous,—time and circumstance alone being required for the development of the disease.

In intimate relation with this question is that of the probability or otherwise of an increase in the prevalence of the disease amongst such a leprous community as exists in Kumaon. Fortunately it would appear that, *pari passu*, with the active manifestation of the disease, a tendency to sterility is also induced; moreover, the mortality among the children of lepers (even among such of them as are born before leprosy has manifested itself in the parents) appears to be abnormally high, so that the probable aggregate of the number of the offspring of lepers is to a very appreciable degree less than that furnished by non-leprous individuals. It is therefore evident that unless there be influnces other than heredity at work in the locality tending towards the production of the leprous condition, no serious increment need be apprehended. It will be our endeavour to ascertain on a future occasion whether any such leprosy-inducing conditions can be detected in the specially affected localities.

With regard to the latter, we have drawn attention to the fact that the malady is far more prevalent along the Nepal frontier, a country in which a very large proportion of lepers is found, and it is believed that no organised attempt of any kind exists in it to relieve their sufferings. Indeed, the reverse is not uncommonly stated. Under these circumstances it is, perhaps, not strange that these districts should be exceptionally afflicted, especially when it is considered that the records of the Almora Leper Asylum show that one-fifth of the total number of the inmates who have received shelter since the institution was established have come from Nepal.

We may find that personal examination into the facts along these specially affected border parganas will dispel the plausibility of such an inference, but at present we are inclined strongly to attribute the exceptional prevalence of cases of leprosy in this part of Kumaon in a great measure to its having to give shelter to more than its own share of lepers—to support more, in fact, than is contributed to the population by its own quota of leprous stock.

We have abstained from making any observations regarding the pathology of leprosy on the present occasion. It will be more convenient to describe this portion of the inquiry when our microscopical investigations of the diseased tissue have been completed. These, for the greater part, we propose to carry out in Calcutta, where the Leper Asylum and the hospitals offer peculiar facilities for prosecuting researches of this character.

CALCUTTA,
November 1876.

ENTERIC FEVER PATHOLOGY.

UNDER the above heading in Dr. Lewis's journal for 1881 there is the following entry:—

"During July and August I made numerous attempts to obtain satisfactory life size photographs of enteric-fever intestines, but owing to the uncertainty of the light during the rains at SIMLA, it was found very uncertain work—it being almost impossible to obtain sufficient density with Wratten and Wainwright's gelatine plates—the pictures were nearly all either over or under exposed. During the last few days, however, the photos obtained were very satisfactory, so I jot down the experience for future guidance.

"Sept. 5. The sun clouded just to the extent of permitting me to look at it without really blinking. The preparation and table taken out into the open air. The piece of intestine carefully stitched on to a piece of glass, slightly larger than the preparation, and fastened on to a deal board [over which some black velvet has been spread] by means of four shortened black pins.

"The preparation placed about $6\frac{1}{4}$ inches in front of a No. 1 symmetrical lens (Ross's 3″ focus), and the ground glass of camera about $6\frac{1}{4}$″ from back glass of lens. The object very carefully focussed by means of a 3″ objective mounted in a cardboard tube of suitable length, so as that the focus of the image should be exact when the tube rested on the smooth surface of the ground glass. This accomplished, apply No. 5 stop, which brings the image sharp to the edges of a 5×4 plate. Exposure 80 to 90 seconds."

The plates were developed with pyrogallic acid and ammonia, and generally they were found to require intensification.

October 1*st*, 1881.

Six negatives were selected and despatched to Major Waterhouse, 40, Hamilton Terrace, London, N.W., for reproduction by the Autotype process, or any other he might select.

September 23*rd*, 1881.

PLATE XXXII.

FIG. 1. [No. 1 Symmetrical lens, 5 Stop 60 seconds.] *The intestines of a middle-aged European* who died at Berlin about January 1879—a preparation which I selected from some of those produced at Professor Virchow's demonstration.

FIG. 2. [No. 5 Stop 90 seconds, diffused light.] *The intestine of a Soldier* who died at Bareilly in 1880. Received from Dr. Hoystead.

PLATE XXXIII.

FIG. 3. [No. 5 Stop 60 seconds.] *Typhoid intestine* from preparation No. 100, Series IX., Medical College Mus. Catalogue. A Hindoo aged 34 who died in the Medical College Hospital about the 7th or 8th day of the disease. Received from Dr. McConnell.

FIG. 4. [15 seconds Stop ?.] From a *native Sepoy* (Jerwah) 43 A. L. I. Gowhatty, presented by Dr. O Brien (No. 97, Series IX., Medical College Catalogue), age of patient 22. He died on the 14th day of the fever

PLATE XXXIV.

FIG. 5. *Intestine of a native Hindu* who died on the 12th (?) day of disease. No eruption; a patient of Dr. Chuckerbutty's. 13th *September*, 1865. Received from Dr. McConnell.

FIG 6 [Stop No. 5, 80 seconds.] From 10, Series IX., Medical College Mus. Catalogue. Subject, *a Hindu female*, aged 15. Duration of disease not certain, but believed to be from history of friends, 14th to 18th day of disease. Received from Dr. McConnell.

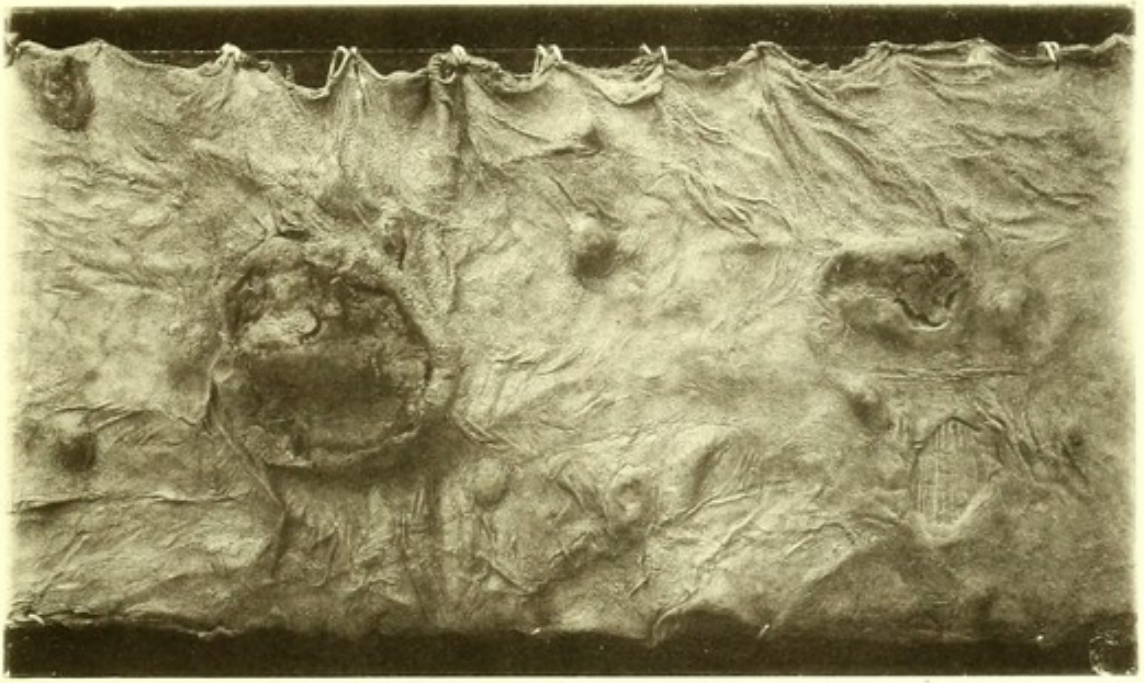


Fig. 1. *Natural size.*

[In Europe.]

Fig. 2. *Natural size.*

[In India.]

T. R. Lewis, *fecit.*

[*To face p.* 488

THE INTESTINE IN ENTERIC FEVER.

(IN EUROPEANS)

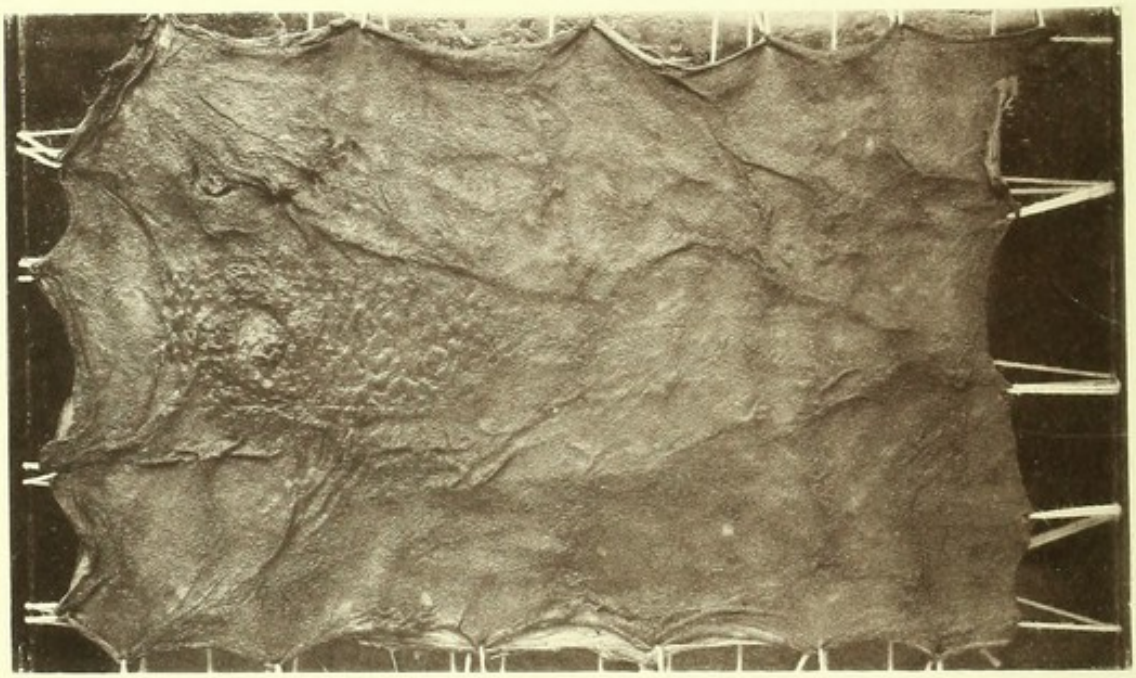


Fig. 3. *Natural size.*

[From a Hindu–Age 34.]

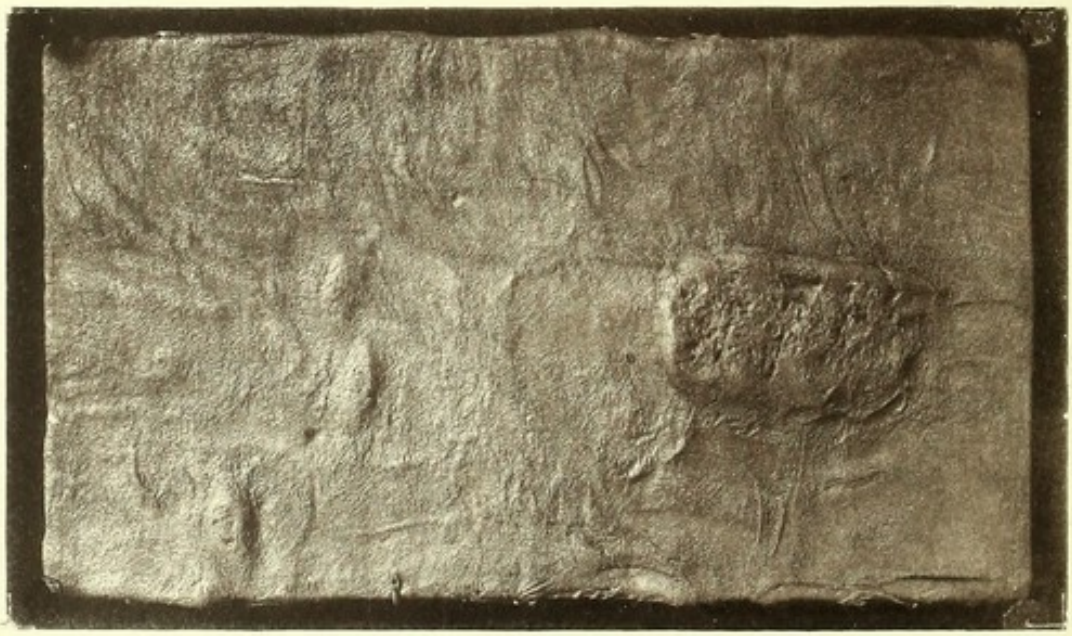


Fig. 4. *Natural size.*

[From a Sepoy–Age 22.]

T. R. LEWIS, *fecit.*

THE INTESTINE IN ENTERIC FEVER.

(IN HINDUS.)

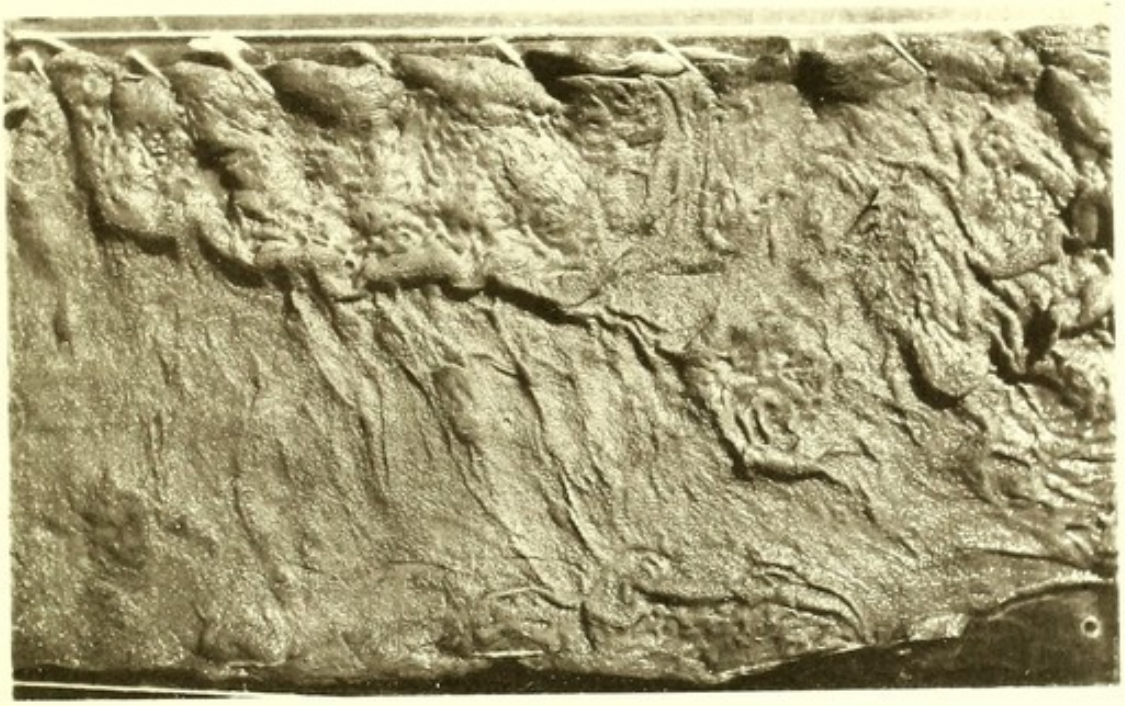


Fig. 5. *Natural size.*

[From a Hindu.]

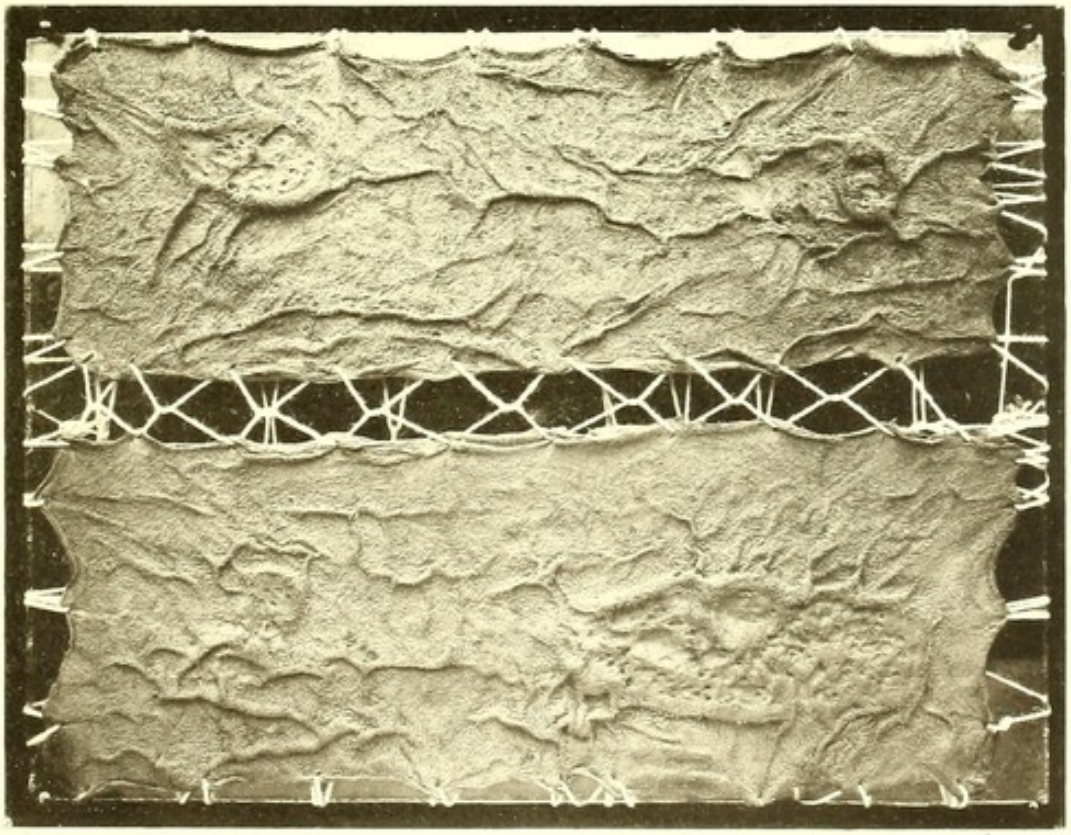


Fig. 6 *Natural size.*

[From a Hindu—Age 15.]

T. R. LEWIS, *fecit.*

THE INTESTINE IN ENTERIC FEVER—IN HINDUS.

(Cicatrices)

PART III.

HÆMATOZOA AND OTHER PARASITES.

A REPORT

ON THE

BLADDER-WORMS FOUND IN BEEF AND PORK.

BY

T. R. LEWIS, M.B.

1872.

In reporting upon the microscopical characters of the "cysts" sometimes found in cattle slaughtered in various parts of India, notably in the Punjab, it has been considered expedient to take up the subject of cyst-affected pork at the same time, as the remarks which apply to the one kind apply in great measure to the other. I am indebted to Assistant-Surgeons W. H. Jameson and G. Andrew, for numerous examples of ration beef thus affected from Rawul Pindi and Fort Attock. The samples of affected pork have been chiefly obtained from the Chinese slaughter-houses located in the north-western suburbs of Calcutta. It has been with the greatest difficulty that the latter could be obtained; personal applications to the various Chinese pork butchers were found to be quite useless. The proprietors seemed to be under the impression that my visit to their establishment had some connection with the recent slaughter-house reforms in the municipality. The service of a couple of low-caste men (*domes*) having been enlisted, fresh specimens were obtained from time to time. These men are said to consume a goodly portion of this pork, which is sold to them at a very cheap rate.

I have, however, not been so fortunate in obtaining many fresh examples of cyst-affected beef. The native butchers declare that it is scarcely ever met with in Calcutta, and the Europeans in charge of the slaughter-houses state that it must be very rare indeed; one of them informed me that during the six months that he had superintended a slaughter-house, not a single example had come under his notice. I am not quite certain that the majority of the men thus in charge have any definite knowledge as to the appearance or nature of these "cysts." That they are occasionally met with in the beef supplied in Calcutta, there is no doubt, and perhaps more frequently than is imagined; but I confess that after trying in vain for months to obtain a sample, I felt greatly surprised at having after all to make their acquaintance, for the first time here, in a cold sirloin placed before me at breakfast, and off which

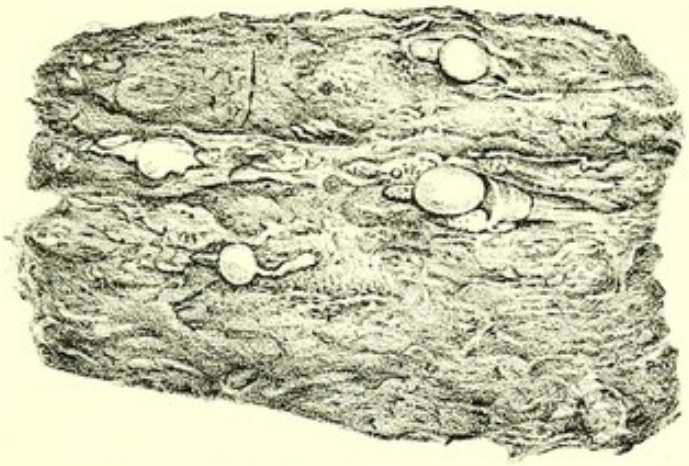
I had dined on the previous evening without the slightest suspicion. The beef, it seems, had been obtained at the Dhurumtollah bazaar in the usual way. Being anxious for a fresh supply for the purposes of experiment, a man was forthwith dispatched to the same butcher, but the answer was, "All sold!" As the specimen thus obtained presented a highly characteristic appearance, it was photographed (natural size). In this manner a more clear idea of the general aspect of cyst-affected meat, which had undergone the process of cooking, may be obtained than from any verbal descriptions or pencil drawings which I would be able to make.

The term "measly" usually applied to beef and pork thus affected is probably derived from the speckled appearance of the meat (measle, a spot), when looked at along the course of the muscular fibres. Small greyish-white bladders are seen lying between these fibres, tapering at both ends, not unlike a grain of oats in form and size. When mature, they are usually a little larger than this, the measle of pork being generally somewhat larger than the measle of beef. Otherwise there is no appreciable difference to the naked eye. In photograph No. 1, Plate XXXV, a piece of fresh uncooked meat thus affected is shown, of the size of the original. It may be observed that the long diameter of the cyst corresponds with the course of the fibres.

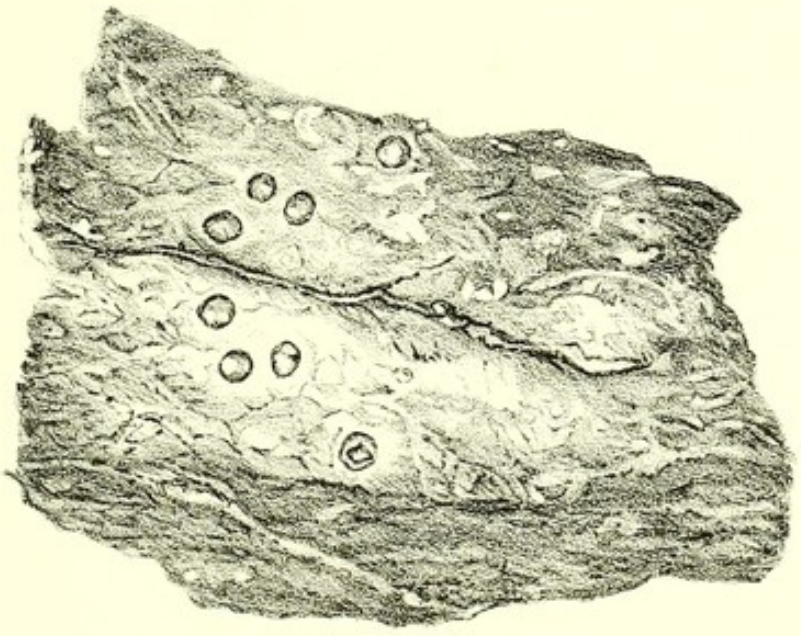
These bodies have been for a long time described under the names of "bladder-worms," "cysticerus cellulosæ," "telæ cellulosæ," etc.; but it is only since a comparatively recent period that their real nature has been satisfactorily explained. It was long suspected that they were somehow connected with tape-worm, the more general belief being that they were the young of these parasites, not capable of further development, which had found their way into places not adapted to their growth. It is now, however, definitely settled that these bladder-worms form a distinct and necessary stage in the life-history of tape-worms; each variety of the latter having a corresponding bladder-worm variety, which either develops into it, or remains undeveloped altogether. The generic connection briefly stated is as follows:—The tape-worm is the sexually mature parasite. It attains this maturity in the intestinal canal of man and of animals. Here also the ova are fecundated, and more or less matured. Every segment of a tape-worm, having its sexual apparatus complete in itself, is capable of producing many thousands of ova, although the largest diameter of the segments of the mature worm found in the human subject, roughly speaking, does not exceed half an inch. These eggs are necessarily therefore very minute; a heap of about five thousand of them would not exceed the size of a small shot. A good idea of their microscopic appearance may be obtained by reference to the accompanying litho-plate from a micro-photograph (No. 3, Plate XXXVI), which shows three of the ova in the midst of some of the calcareous corpuscles found in the tissue of tape-worms.*

* In connection with the accompanying attempts at the representation of minute structure by microscopic-photography (it is believed, for the first time in India), I desire to acknowledge the great assistance which has been received from Assistant-Surgeon G. E. Dobson, M.B., without whose aid, indeed, it would have been impossible for me to have carried out the experiments in this direction.

It is hoped that more successful representations of microscopic objects will in time be obtained than



No. 1.—A piece of fresh, unboiled "measly" pork, showing four "cysts." Natural size.



No. 2.—A slice of "measly" beef, roasted, four cysts having been cut through. Natural size.

PHOTOGRAPHS OF BLADDER-WORMS IN BEEF AND PORK.

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These ova are distributed in various ways; some find their way into the intestines of the animals adapted to their development; here the ova become ruptured, and the embryo which each contains escapes into the intestinal canal. Now the embryo is provided with six very minute hooks (not always observable through the "shell" of the egg, and not visible in the particular samples photographed, possibly the samples were young), two in front and two on either side, by which means they are enabled to bore or burrow their way through the intestinal walls, and pass on into the various tissues of the animal, somewhat after the manner of a mole, the anterior pair of hooks acting the part of the snout and the lateral pairs that of the fore-legs; * the particular tissue selected depending on the particular species of parasite. Those affecting cattle and pigs lodge themselves between the fibres of muscular tissue, while those of rabbits generally select the peritoneal membrane, and those of sheep are found on the surface of the brain, giving rise, in them, to the disease called "staggers."

The embryo having thus lodged itself, enters on the second stage of its existence, the encysted stage, which, in the case of the species found in cattle and swine, constitutes what is termed "measles."

This has been over and over again proved by experiment as follows:—ova-containing segments of the Tænia affecting the human subject have been administered to young pigs and *calves*† in some suitable fluid, such as milk and gruel, and when the animals were slaughtered, after a period of from two to three months, the flesh of the greater number has been found thoroughly measled, while evidence of the commencement of this condition may be detected in a fortnight or three weeks.

As before stated, the bladder-worm in beef and pork presents the same appearance to the naked eye. On separation of the muscular fibres in which the parasite has lodged itself, a tough little fibrous bag may be pinched up with the forceps. This constitutes the "cyst" which has been formed around the worm, and is probably derived from the fibrous tissue or sarcolemma of the muscle with which it is microscopically identical. This little sac is firmly attached to the flesh, and cannot be removed except by tearing it away from the latter. On carefully snipping off one of the ends of this fibrous bag and gently pressing it with the point of the finger, another little bladder of a much more delicate appearance, with a shining surface,

those now presented; this method of illustrating microscopic objects having of late become of great importance, as by the new heliotype-process, *permanent* reproductions are obtainable in every way equal to the originals, and at less expense than engraving.

This process is, I understand, being at present perfected and adapted for India by Captain Waterhouse, Assistant Surveyor General.

(Since the submission of this Report, it has however been found that the arrangements are not yet sufficiently matured to ensure the supply of a sufficient number of copies within a given time; they have therefore been very carefully lithographed at the Office of the Surveyor General under the superintendence of Captain Waterhouse.)

* P. J. Van Beneden, "*Mémoire sur les vers intestinaux.*"

† It is a remarkable circumstance that, as far as is hitherto known, pigs over a year old and grown up cattle cannot be infected; with young pigs and calves only have infection experiments proved successful

may be squeezed out. This is the bladder-worm itself. If the photograph of the transverse section of the roasted piece of measled beef (No. 2, Plate XXXVI) be now examined carefully, a group of four cysts will be seen cut through the centre. The upper slice held up by pins represents their appearance when empty—a semicircular cavity between the muscular fibres formed of the fibrous tissue alluded to, whilst the corresponding halves are seen below, each containing its little bladder-worm, here shrivelled and dead, and not unlike a grain of sago, in size and form (hence the name "sago" applied to this condition in some of the slaughter-houses), but in its natural condition filling the fibrous bag which enclosed it, for the shrivelled vesicle is distended with fluid during life. As long as this sac remains entire, the amount of fluid contained in it may be made to vary, by simply immersing the parasite in fluids of various densities in accordance with the well known laws of diosmotic action. This is doubtless the way by which nourishment is conveyed; the plasma of the blood circulating through the muscle exudes into the cavity of the fibrous bag (on the outer surface of which numerous minute vessels may be seen to anastomose), and between the fluid contents of this bag and the fluid contents of the bladder immersed in it constant interchanges must take place, for the bladder-worm itself has no vascular connections.

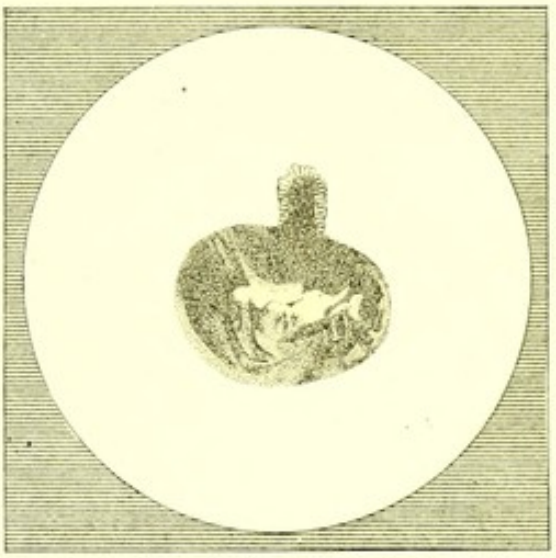
If this delicate vesicle be closely observed, a hard whitish tubercle will be seen through the walls, about half the size of a grain of rice, which, on gently pressing the cyst between two pieces of glass and examining under a low power, will be found to consist of a solid substance, curled upon itself (generally) as shown in micro-photograph No. 4, Plate XXXVI, which represents a sample of the beef bladder-worm magnified five diameters. The bladder is unruptured, and the curled object seen through the walls is the "head and neck" of the parasite.

If the cyst be now transferred to the stage of a dissecting microscope and very gently pressed with suitable needles, the incurved portion may, after a little practice, be made to turn out of its sac without in the least degree tearing it, although the sac is considerably more delicate than tissue paper, as a small orifice may be perceived with the aid of a lens, which orifice corresponds to the slight concavity of the vesicle observable in the micro-photograph, and through this the "head and neck" may be pressed out. The first stage of this operation is represented in a micro-photograph (No. 5, Plate XXXVI) of a small beef cyst, magnified five diameters, and the completely everted condition in micro-photographs, Nos. 6 and 7; the former being a very satisfactory representation of the pork bladder-worm, and the latter of the bladder-worm of beef, both magnified to the same extent. It is now that the distinction between the two parasites becomes evident. This distinction will be referred to farther on.

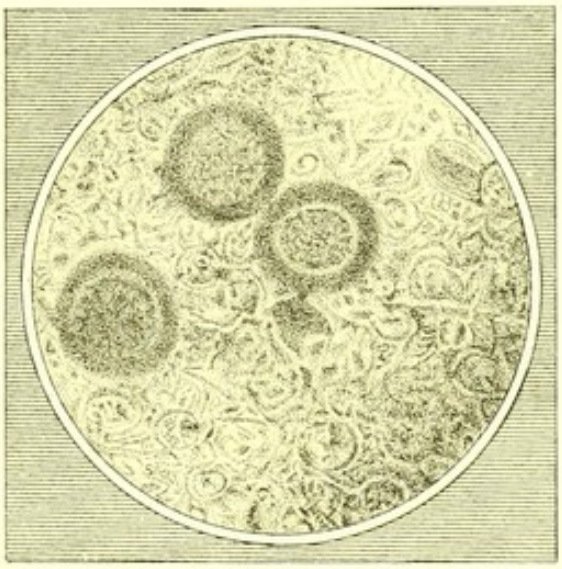
Microscopists differ very much as to the mode of growth and anatomical arrangement of the "head and neck" in the encysted condition. I venture to give the following description as briefly as possible of these structures, based on at least a hundred dissections of the cysts in various stages of development.

The bladder-worm having been placed in a shallow trough provided with a cork

No. 4.—Mature Bladder-worm, coiled within its sac, magnified 5 diameters.



No. 5.—Mature Bladder-worm, "head and neck," partly turned out, magnified 5 diameters.



No. 3.—Ova of Tape-worm, magnified 350 diameters.

No. 6.—Completely everted Bladder-worm of pork, magnified 5 diameters.

No. 7.—Completely everted Bladder-worm of beef, magnified 5 diameters.

MICRO-PHOTOGRAPHS.

To face p. 494.

bottom, a little water is added so as to cover the object, and the whole placed on the stage of a dissecting microscope. The bladder is slit open with fine scissors at the part opposite to the orifice already referred to; the membrane reflected from the contents on all sides, and held down in this condition by means of fine pins inserted into the underlying layer of cork (Fig 24). The inner surface of the membrane when

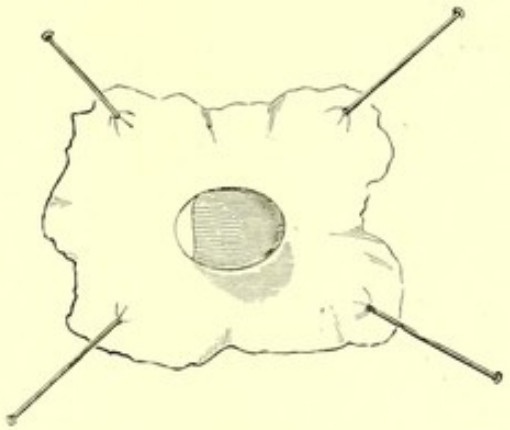


Fig. 24.—The ruptured bladder spread out on a layer of cork by means of pins, with the coiled up parasite adherent to its inner wall. Magnified about five times.

thus spread out has been well discribed by Mr. Rainey, in the Philosophical Transactions, as presenting the appearance of being sprinkled over with powdered glass. The parasite, however, is not yet at liberty, but remains firmly rolled up, and if a needle be gently drawn over the mass, it will be found that a perfectly even surface is presented, and a hair passed into the original orifice in the bladder on the opposite side (as here placed) will be found to press a layer of tissue before it; in fact, the

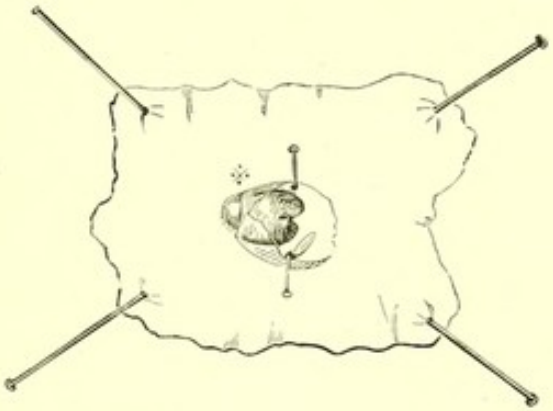


Fig. 25.—As Fig. 24, but the "receptaculum" split open, the rugæ of the coiled up neck brought to view, as well as the orifice by which the parasite eventually escapes. Magnified about 5 times.

part touched by the needle and pushed forward by the hair consists of an exceedingly delicate membrane (the "receptaculum") enveloping the coiled up "neck." This, again, may be laid open with a sharp dissecting knife, carefully reflected and held down by the smallest pin obtainable (Fig. 25). The membrane in contact with the

part marked with an asterisk cannot be reflected, but remains firmly attached to the coiled heap. The reason for this will soon become evident.

The portion of the neck nearest the orifice is movable, and may be readily drawn on one side by means of a little hook (Fig. 26), when the cavity in which the

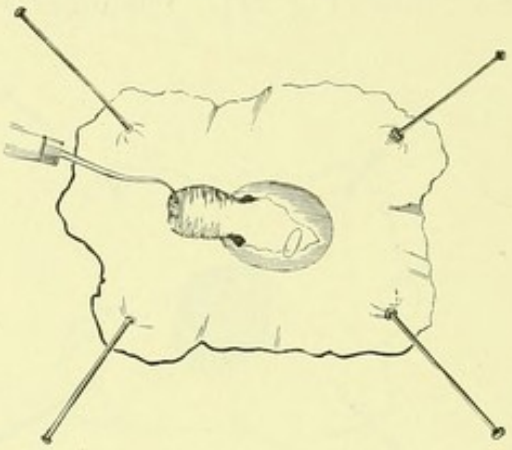


Fig. 26.—The "head" and "neck" pulled out of the "receptaculum" through the rent. Magnified about 5 times.

worm has lodged will be brought well into view. By fixing a short hair into a small needle-holder, and using it as a probe, it will be ascertained that the delicate inner membrane just reflected is continuous with the neck of the worm at the end furthest from the orifice, just as the mucous membrane of the mouth is continuous with the skin of the lip, or that the finger of a glove is continuous with the hand-portion when the latter is pulled over the former, so that the reason why, at the corresponding end on the opposite side, the membrane could not be reflected becomes evident at once.

This arrangement becomes still more clear when the "head" and "neck" are

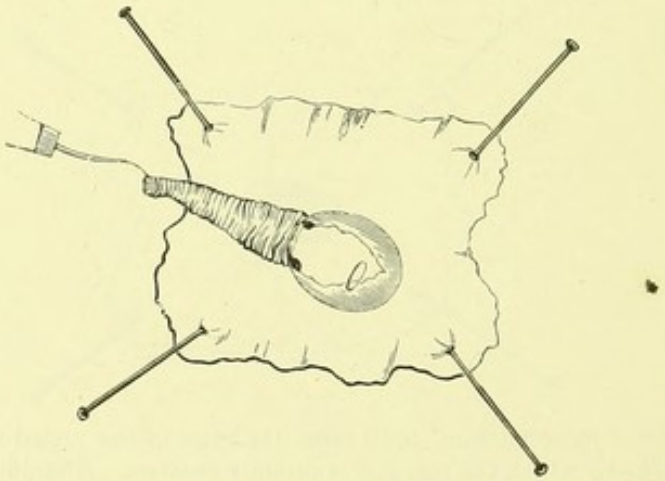


Fig. 27.—As Fig. 26, with the "neck" everted and uncoiled. The head is still inverted. Magnified about 5 times.

turned out and made to assume their destined appearance. This may be done by slight pressure and gentle use of the hook as shown in the third woodcut. The "neck" will then be turned inside out, and become uncoiled at the same time, as seen in Fig. 27, which represents the greater part of the neck thus exposed; the

head portion, however, is seen to be still unfolded. Unless the parasite be alive, its further unfolding is attended with considerable difficulty, and can seldom be satisfactorily accomplished, especially if it has been preserved in glycerine. Under other circumstances, the head is readily squeezed out. If a hair be now inserted through the orifice in the outer cyst, and tied round the neck of the completely unfolded worm, this portion may be pulled out, as represented in Fig. 28, and more

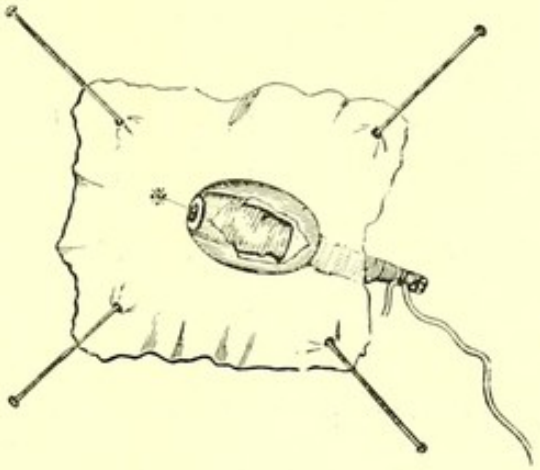


Fig 28.—The "head" having been everted, a hair was introduced through the orifice fastened to the "neck" and the parasite withdrawn from the "receptaculum." The latter is seen to be continuous with the "neck" itself Magnified about 5 times.

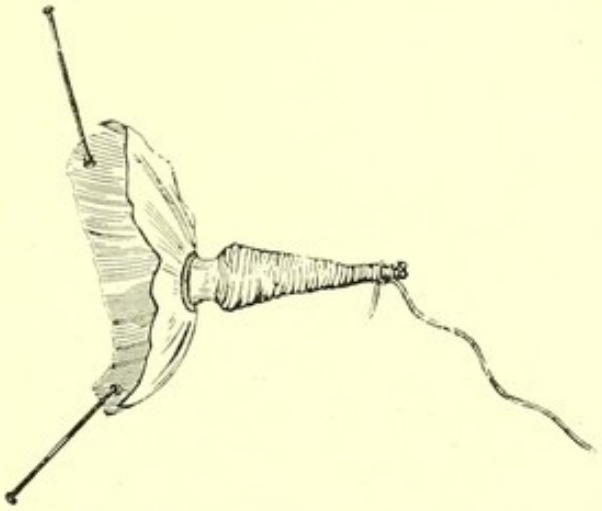


Fig. 29.—As Fig. 28. The worm completely withdrawn from its enveloping vesicle. Magnified about 5 times.

completely so in Fig. 29. The part of the worm marked with an asterisk in the woodcut (Fig. 28) is not hollow, as one might suppose from observing that the neck and the hood surrounding it are continuous, for a little membranous tissue stretches across it, differing in structure (more especially by the entire absence of the calcareous corpuscles to be hereafter referred to) from the neck and its reflected continuation; the little sac acting as a sort of diaphragm, so that air or a coloured solution blown into the outer bladder does not extend up the neck of the worm. This, to the best of my knowledge, is a correct anatomical description of the encysted parasite, the

somewhat complex details of which will, perhaps, be made clearer by the accompanying semi-diagrammatic sketch. (Fig. 30.)

The only marked difference between the measle of pork and the measle of beef and veal (for calves are found to be much more frequently infected than grown-up cattle) is found in the so-called "head." The two kinds are provided with small circular discs or suckers. These are well shown in the micro-photograph (No. 8, Plate XXXVII), representing the "head" of a beef cysticercus, magnified thirty-five diameters. Suckers have been mistaken at various times for eyes, for nostrils, and for mouths, with none of which organs are the parasites provided. In live specimens the suckers are frequently seen to protrude and retract. They are used by the worms for attaching themselves to the intestinal walls, when they get transferred thither. A fifth sucker may nearly always be detected in this species, although the statement has often been called into question, but this fact is indisputably proved by its presence in the print of micro-photograph No. 9, in which the head of a beef cysticercus, magnified thirty-five diameters, has been snipped off with a scissors and carefully dissected, under water, on the stage of the microscope, so as to show the *five* suckers

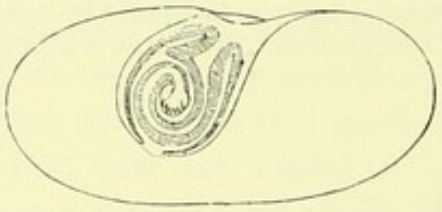
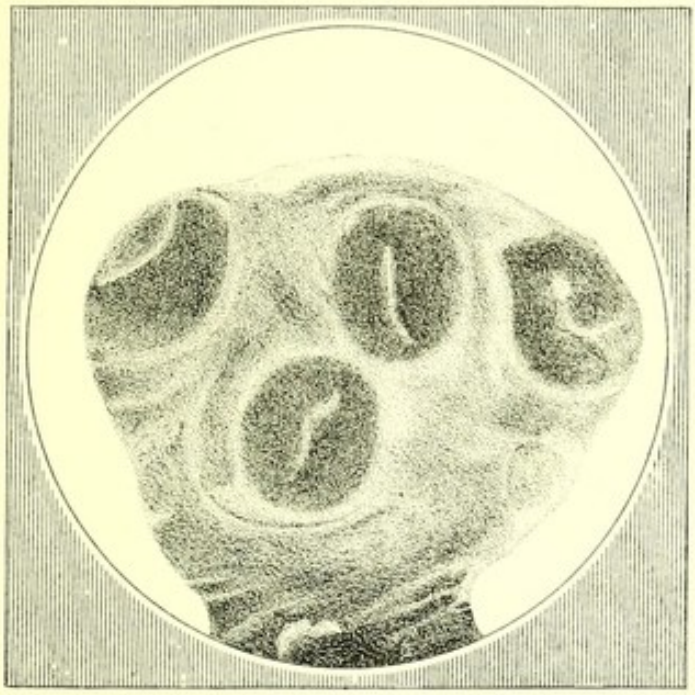


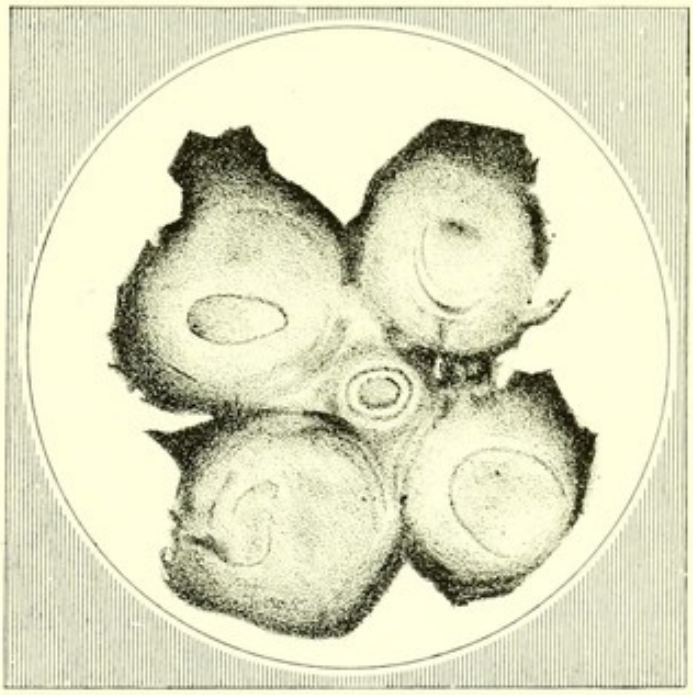
Fig. 30.—Diagrammatic, showing the inverted and coiled condition of the "head" and "neck" with the relation of the latter to the receptaculum.

when spread out between a covering glass and slide. In the spot corresponding to this central rudimentary sucker or surrounding it, a series of sharp pointed hooks is developed in the pork variety, which constitute the essential difference between these two species of bladder-worms. The relation of the hooks to the four suckers is well shown in the micro-photograph (No. 10, Plate XXXVII), of the head of a pork bladder-worm, dissected and spread out as in the other species. The hooks are arranged in two rows, the inner row being the larger, twelve or thirteen, sometimes more in each row; the points of both rows being directed forwards and outwards, so that this species is thus enabled to take still firmer hold of its "host" than those found in beef and veal. Micro-photograph No. 11 represents the ring of hooks in the dissected preparation more highly magnified than in No. 10; a one-inch objective being used in the latter case and a quarter in the former.

Excepting that the pork worm is provided with the hooks just described, and that the beef worm presents a fifth or central sucker, there is no difference in the microscopic appearance of the two varieties. In both the "head" and "neck," together with the reflected portion of the latter, are thickly scattered with oval calcareous

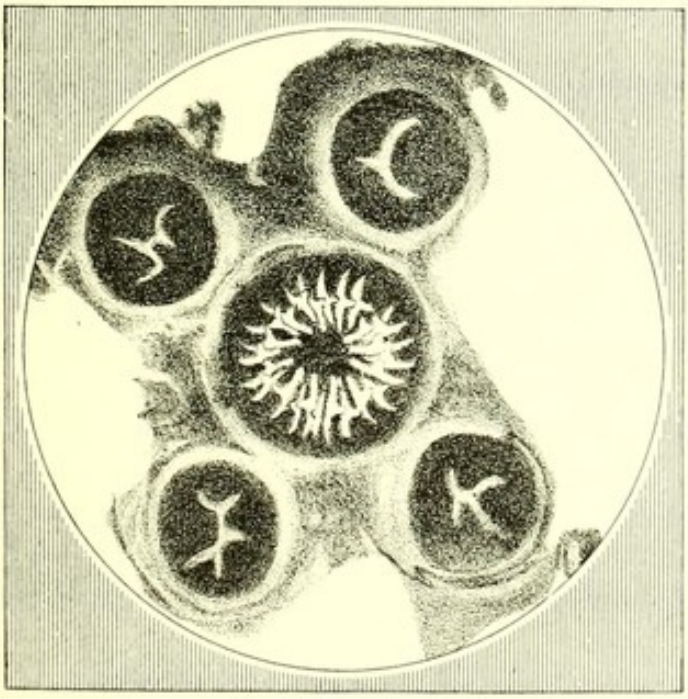


No. 8.—"Head" of Bladder-worm of beef, magnified 35 diameters.

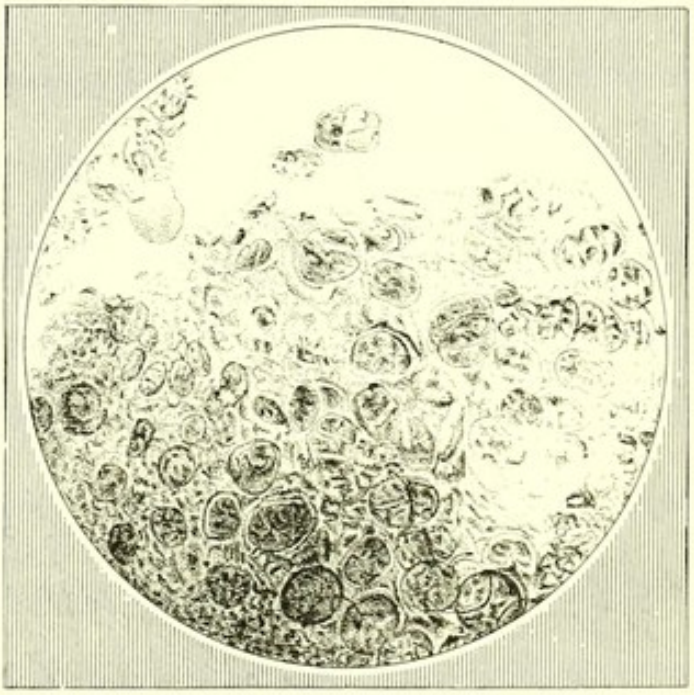


No. 9.—"Head" of Bladder-worm, dissected out, magnified 35 diameters.

No. 11.—The double row of hooks of the pork Bladder-worm, magnified 100 diameters.



No. 10.—"Head" of Bladder-worm of pork, dissected out, magnified 35 diameters.



No. 12.—"Calcareous Corpuscles" found in Bladder-worms, magnified 400 diameters.

MICRO-PHOTOGRAPHS.

To face p. 499.

particles, some of which present a laminated appearance very like a section of "alternating calculi." These are acted on by acids, but even strong alkalies scarcely affect them, and I have failed to detect any great difference in their appearance after subjecting them to the flame of a blow-pipe. They have been mistaken for eggs, but they are very different in appearance from ova, as may be seen by comparing micro-photograph No. 12, Plate XXXVII, representing these particles from a beef measle, magnified by a $\frac{1}{8}$ objective, with No. 3, Plate XXXVI, in which three eggs from a mature tape-worm are represented as well as the calcareous corpuscles (which lie on a lower plane and consequently somewhat out of focus).

In the cysticercus stage these parasites contain no ova, are sexually immature, and incapable either of further development or of reproducing others of their like, until they find their way into the intestinal canal of the animal which devours the flesh in which they are encysted.

With the view of ascertaining whether the particular bladder-worms under consideration would develop in other than the human intestines, I have repeatedly administered flesh containing numerous cysts to animals; nine dogs (three being puppies) have been thus experimented upon, their excreta examined daily until slaughtered at periods varying from a fortnight to three months, but in no case could I satisfy myself that these cysts had left a trace. They were all evidently digested, together with the meat which contained them. Tape-worms there certainly were, but of a very different kind to those found in the human subject, so that the dissemination of the human tape-worm by dogs eating the carcases of pigs and cattle is not probable. With man, however, the case is different, for it has been conclusively proved that, when *raw* measly pork is eaten, tape-worm (*tænia solium*) may be produced. Professor Leuckart, of Giessen, the chief authority on this subject, has actually produced this tape-worm in a prisoner who had been placed at his disposal for the purpose. The evidence is very nearly as conclusive in connection with the beef and veal measle, for Assistant Surgeon Oliver, R.A., has succeeded in producing (in the Punjab) the tænia mediocanellata in two low-caste natives, from whom no previous history of the existence of tape-worm could be obtained; moreover, the identity of appearance of the head of the mature hookless tape-worm (*tænia mediocanellata*) with the head of the encysted worm in beef, the fact of tape-worm being endemic among the Abyssinians, who do not eat pork, but only the flesh of cattle, and that in the raw state, as well as the fact that the ova procured from the tænia mediocanellata in man have repeatedly produced measles in calves, leave no reasonable doubt on the subject.

In considering the most practicable methods of reducing the risk of mischief arising from the consumption of meat in localities where measled animals are numerous, it is of importance to bear in mind the ages at which the animals are slaughtered in these districts. As already stated, pigs under a year old cannot be infected, nor can grown-up cattle, and in connection with the latter class of animals, Cobbold has made

the most important practical observation that, when a calf is infected, and slaughtered some nine or ten months subsequently, the cysts will be found to have become degenerated in all parts of the body; gritty calcareous spots (*perfectly harmless*) alone remaining to mark the situation formerly occupied by the living parasite. Such being the case, the probability of the flesh of cattle being infected with cysticerci diminishes in proportion as the animal is over two years of age. It is believed that a somewhat similar rule may be applied to pigs, although no definite experiments have, as far as I have been able to ascertain, been recorded. In Calcutta it is the young growing pig which is liable to be infected in this manner, and many of the Chinese butchers are aware of this fact, so that the slaughtering of a pig suspected of harbouring measles is delayed for some months, even though the animal be fat and in every other way eligible for the market.

The diagnosis of this condition in pigs and cattle before death is by no means easy, unless the number of parasites be very great; although in some of the seaports of Northern Europe, trained men have been appointed, who have acquired considerable precision in detecting the disease in pigs intended for exportation. The general condition of the animal may be bad or excellent; symptoms of local irritation may exist or they may not, so that no precise method of diagnosis can be given. If, however, the cysts be extensively distributed throughout the tissues of the animal, their existence may very generally be detected by passing the finger along the eyelids or inserting it into the mouth, and feeling more especially the mucous membrane at the root of the tongue, beneath which the little cysts may often be felt as nodules about the size of peas. If felt, the slaughtering of the animals should be deferred for six or twelve months, or until these nodules disappear. The method of detecting the presence of *trichinæ** in the flesh of the pig and in human flesh infected thereby, namely, cutting out a fragment of muscle with a sort of harpoon, is not applicable to the detection of cysticerci, for in probably nine cases out of ten the piece of muscle thus scooped out would contain no trace of the parasite.

The only reliable preventive measure at our disposal is proper cooking of all meat; by this I mean exposing every particle of the meat to an amount of heat sufficient to destroy the vitality of each cysticercus.

With the view of ascertaining definitely what exact amount of heat is required to do this, I have made numerous experiments with cyst-infected meat in all stages of growth, a brief *resumé* of which is here given. When a living cysticercus is removed from its host and placed on the stage of the microscope and watched for some time, its muscular tissue is seen to contract and expand, and it is even able to shift its position on the slide. Frequently, however, no such indications of life are

* It is by no means uncommon to find that the prevalence of measled meat in a locality has been attributed to the existence of the *trichina spiralis*, which gives rise to what is called the *trichiniasis* or the "flesh-worm disease" so prevalent in Germany a few years ago, and undue alarm has arisen from the misconception. This worm belongs to a totally different order, its mode of growth and multiplication is different, and the result of infection on the human body vastly more serious.

manifested unless the slide be slightly warmed or irritants applied to the substance of the cyst, whilst others, on the other hand, although in no way differing in appearance from those just mentioned, cannot be made to manifest the slightest indications of life, being in reality dead. It was therefore soon found whilst experimenting on the effects of temperature, that actual destruction of the substance of the cysticercus or even perceptible alteration in its appearance was not necessary to bring about its death, whereas the non-manifestation of movements did not prove that life was extinct.

In order, therefore, to decide this point satisfactorily, it was considered that electricity might be advantageously resorted to, in addition to ordinary irritants, seeing that as long as muscular tissue preserves its vitality, a current passed through it will cause it to contract. The wires from a battery were consequently attached to the stage of the microscope and "induced currents" transmitted through the substance of the bladder-worm under observation.*

The first step taken was to ascertain the temperature to which meat is exposed in the ordinary methods of cooking. Pieces of ordinary meat weighing from four ounces to several pounds were selected, and immediately on removal from the source of heat the bulb of a thermometer was introduced into its substance at various stages during the process of cooking.

The temperature of portions of beef removed from a boiler of beef-tea in which they had been immersed and kept at 212° for over an hour varied from 190° to 200° Fht.

The temperature of legs of mutton which had been put into the boiler almost as soon as the water was put into it, averaged 140° in the interior at the moment the water had reached the boiling point (212° F.), and after boiling for five minutes the temperature had reached 170°. Chops and steaks before being considered well done are exposed to a temperature of from 170° to 180°; at 150° they are considerably underdone, the red colouring matter has not disappeared, nor does it disappear until the meat has been subjected to about 10° more heat.

In no instance did I observe that the cook had served meat the temperature of which, when tested with the thermometer, did not exceed 150° F. At a lower temperature than this the meat appeared raw, and would in all probability have been returned to him.

The next point to be ascertained was the amount of heat these entozoa would resist when placed in pure water, in salt and water, or without the addition of water. After satisfying myself that the samples under observation were alive, a dozen or two were picked out of the affected meat, leaving a little of the latter attached, so as not

* Should these or like experiments be repeated by others, it may be well to draw attention to the fact that, if the conducting wires are accidentally permitted to touch the brass work of the microscope, an extremely painful shock may be received by the eye of the observer, which might, as occurred to myself, necessitate a cessation from microscopic work for some days.

in any way to increase the "tendency to death" which laceration of the capsules might do, and yet not permitting too much of the meat attached, so as materially to modify the amount of temperature to which they were exposed. They were then subjected to a temperature varying from blood-heat upwards, and kept so for definite durations noted at the time. As the data thus accumulated would tend rather to confuse than to elucidate were they given in detail, the following general deductions may be considered sufficient:

(1).—That exposure to a temperature of 120° F. for five minutes will not destroy life in cysticerci, but that they may continue to manifest indications of life for at least two or three days after such exposure;

(2).—That exposure to a temperature of 125° for five minutes does not kill them; but

(3).—After being subjected to a temperature of 130° F. for five minutes, they may be considered to have perished. After exposure to this and higher temperatures, in no instance have I been able to satisfy myself that the slightest movements took place in their substance when examined under even a high power. At least it may be confidently asserted that, after exposure for five minutes to a temperature of from 135° to 140°, life, in these parasites, may be considered as absolutely extinct.

(4).—The presence of salt to the extent used in cooking did not materially modify the result; nor

(5).—Did the fact of their having been introduced into a hot chamber without being immersed in fluid, except that in the latter case the time of exposure required was longer.

In no case was I able to detect a single live bladder-worm in portions of measly meat which had been cooked in the usual way, and even in portions of it which had been rather under than over cooked.

It may, therefore, be inferred that even with ordinary precautions on the part of the cook, the further development of cysticerci will be arrested; it is rarely that persons from preference partake of meat so much underdone as not to have been subjected in *every part* for five minutes to a temperature of from 135° to 140°F., after which exposure it may be confidently stated the entozoa will have succumbed.

ON A HÆMATOZOON IN HUMAN BLOOD:

ITS

RELATION TO CHYLURIA AND OTHER DISEASES.*

BY

T. R. LEWIS, M.B.

FOR many generations writers on medical subjects have maintained that the human blood during certain diseased conditions is invaded by parasites. The opinion most in favour has been that these, in all probability, were in the form of worms, but so far as I have been able to ascertain, it has never yet been satisfactorily demonstrated that this condition really existed.

That certain limited areas of the circulatory tract may become invaded by Entozoa has long been known: the portal vein and the vessels in more or less direct relation with the intestinal canal are the channels which have usually been thus affected; but the parasites found in these situations, such as the Distoma hæmatobium, discovered by Bilharz in 1851, and a few other imperfectly described distomata, are far too large to pass through any but comparatively capacious blood-vessels. The instances on record in which they have been found in vessels beyond these limits are few, and evidently accidental occurrences. None of these therefore, can, I think, be justly described as "hæmatozoa" in the strict sense of the term.

The same remarks apply, with only very slight modifications, to the presence of Echinococci in the blood-vessels, a few young specimens of which have, on rare occasions, been discovered (by Klencke and others) in the general circulation, but then only in vessels of considerable calibre.

It has also been inferred that the progeny of some Entozoa must be carried by the blood-current, as otherwise they could not have reached their destination so rapidly in the various distant parts of the body in which they have been found. That the Trichina spiralis, for example, during its earlier migrations, may be conveyed in this way, is, although strongly denied, I think not improbable. As their presence in

* From "Indian Annals of Medical Science," January 1874.

the blood has not, however, been recognized, either in man or in animals, their sojourn in such channels must at all events be of very short duration.

But that a condition should exist in which human blood should be infested by living active worms in either an embryo or mature state, to the extent hereafter to be described, had, I presume, scarcely been surmised—a condition in which they are persistently so ubiquitous as to be obtained day after day in numbers, by simply pricking any portion of the body, even to the tips of the fingers and toes of both hands and both feet of one and the same person, with a finely pointed needle. On one occasion six excellent specimens were obtained in a single drop of blood by merely pricking the lobule of the ear.

Towards the beginning of July 1872, whilst examining the blood of a native suffering from diarrhœa, a patient at the Medical College Hospital under Dr. Chuckerbutty's care, I observed nine minute Nematoid worms in a state of great activity on a single slide. On drawing the attention of my colleague, Dr. Douglas Cunningham, to the preparation, he fully coincided in my opinion that they were precisely the same kind as those observed by me more than two years previously (in March 1870), as being constantly present in Chylous urine.

In a report on the microscopic characters of choleraic dejecta published at the time, both separately and also in the form of an Appendix to the Sixth Report of the Sanitary Commissioner with the Government of India, I had occasion to allude to this condition of the urine in connection with some cells observed in it, which closely corresponded in appearance with cells constantly present in choleraic discharges, and the opportunity was taken of drawing attention to the Entozoon, which was at the same time figured and described. [See Plate XII.]

For the sake of convenience it may be well to refer to this case again. The patient was a deaf and emaciated East Indian, about twenty-five years of age, under the care of Mr. R. T. Lyons, at the General Hospital, and was kept under observation for a period of two months, during which time his urine continued to present a white, milky appearance, and yellowish-white coagula rapidly formed in the vessel into which it had been voided. When a small portion of the gelatinised substance was teased with needles on a slide, and placed under the microscope, delicate filaments were seen, partly hidden by the fibro-albuminous matter in which they were embedded, and which I at first considered to be scattered filaments of a growing fungus. After being watched for some time, however, they were seen to coil and uncoil themselves, so that all doubt as to their nature was at an end. I had opportunities of showing them on various occasions to several persons, and having perfectly satisfied myself that their occurrence was not accidental (the fact of the patient not being a female diminished the risk of fallacy on this point in no small degree), nor yet the result of subsequent development in the urine, after the manner of the anguillulæ which are so well known to develop in vinegar or

starch-paste, I did not hesitate to draw attention to them as being the probable cause of the obscure disease known as "Chyluria."*

From this period I have paid considerable attention to the subject, and I desire to express the obligations I am under to Dr. Ewart, the Surgeon in charge of the Presidency General Hospital; to Dr. D. B. Smith, the Officiating Principal of the Medical College; to Dr. Edmonston Charles, Professor of Midwifery at the same College, and to Dr. McConnell, the Professor of Pathology, as well as to several others, for the opportunities afforded me for the study of this and of allied conditions of the urine.

A slide containing one or more specimens of this Nematode having been forwarded to Professor Parkes, at Netley, he very kindly showed it to Mr. Busk, whose extensive knowledge in this department of science is well known, and the opinion was expressed by him, that, so far as could be judged from the form and size alone, the worm seemed to belong to the *Filaridæ*.

At this time it was not known to exist in the blood, nor had its minute anatomy been accurately ascertained; however, I do not anticipate that the information acquired since that time would materially alter Mr. Busk's opinion, so that perhaps the name already applied to the Hæmatozoon in the columns of the "Lancet," *Filaria Sanguinis hominis*, may, provisionally, be adopted.†

I am indebted for the greater number of the specimens of Chylous urine which I have examined to Dr. Charles, who with Dr. W. J. Palmer was, I believe, the first to verify these observations, both having had cases of the disease about the same time towards the end of 1870 or beginning of 1871. The fact of Dr. Charles being in charge of the midwifery wards of the College Hospital, has apparently conduced to his being able to aid me so materially, as, strange to say, the patients suffering from Chyluria have, for the most part, been women: in the last case brought to my notice by him, this condition was observed, for the first time, four days after podalic version had been performed.

I have now observed the urine in this condition, associated with more or less

* Subsequent observations in connection with this case will be referred to further on (page 529).

† A medical practitioner in Brazil, Dr. Otto Wucherer, in a paper on "Hæmaturia Braziliensis," in the *Gazitta da Bahia* of December 1868, states that he has discovered a parasite in the urine of a patient suffering from this disease differing materially from the Trematode found by Bilharz in the hæmaturia of Egypt; and that Leuckart, to whom he forwarded specimens, had considered them to be the embryos of some ground-worm probably belonging to the Strongylidæ. Not having succeeded in obtaining the original account, nor seen any figures of these parasites, I am not in a position to form anything like a definite opinion as to the relation which may exist between them and the Filaria here referred to; but judging from the abridged descriptions and measurements which have lately come under my notice, they would appear to present a marked resemblance, and I think that notwithstanding the absence of any allusion to the sheath so characteristic, and during life especially, so *conspicuous* a feature in the latter, with some other discrepancies, it will probably be found that they belong at least to a closely allied species, and possibly may hereafter also be traced to the blood.

marked hæmaturia, in more than twenty patients, several samples having been obtained from nearly all of them: these microscopic Filariæ have been present—in either the urine or the blood, or in both—on every occasion. Of the persons thus affected, five were ascertained to be of pure European parentage, but three of them were born in this country; the remainder were either East Indians or natives, in about equal proportion.

I regret that I lost opportunity of fully ascertaining the previous history of the case in which the Hæmatozoa were first detected. Having satisfied myself of the identity of the worms previously observed in the urine and now in the blood, by careful comparison of their form, structure and measurements, I returned on the following morning to the Medical College for this purpose, but to my great disappointment found that the man had been discharged, at his own request, an hour before my arrival. He had, it appears, suffered from diarrhœa for about a fortnight, which had become greatly aggravated a few days before his admission into hospital; but nothing further could be learnt of the state of his health beyond that he had complained of deafness, especially of one ear.*

He had left no address, except that he was a blacksmith living in a large bazaar in the neighbourhood; but as some three or four thousand persons are crowded into this bazaar, a great proportion of whom are smiths in some form or another, thos acquainted with the intricate geography of such places in the East will not be surprised to learn that I spent a whole afternoon searching for him in vain. I then enlisted the friendly aid of the police, but this also proved fruitless.

A few days after this occurrence, Dr. D. B. Smith informed me that there was a native woman in one of his wards suffering from hæmaturia combined with a Chylous condition of the urine, and very kindly forwarded a specimen of it on the following morning; this urine as usual under such circumstances contained the worms in abundance.

I saw the woman on the evening of the same day, and learnt that the complaint from which she was suffering had first made its appearance during the third month of her last pregnancy, but that it had apparently passed off in about five or six weeks. After the birth of this child, which was now five months old, the disease came on again, she was unable to suckle her infant, the lacteal secretion being altogether absent.†

* One of the patients brought to my notice, who had suffered from Chyluria for several months, had been in hospital for another complaint, and had actually left the hospital without having mentioned a word about the condition of his urine. He stated afterwards that he did not like to do so as it was no great inconvenience to him, and he imagined it was the temporary result of an "indiscretion."

† A case is recorded by Drs. Mayer and Pearse as having occurred in the Madras Presidency, in which a young East Indian woman had suffered after two pregnancies in this manner; she continued to suckle her children uninterruptedly, but on being advised on the last occasion to discontinue doing so, the urine returned to its natural appearance.—*Brit. and For. Med.-Chir. Review, Vol. IX.*, 1852, p. 511.

On pricking her finger with a needle and distributing a drop of blood over several slides, I found that the Filariæ were present in it also.

She remained under observation for a period of about two months, but there was no marked change in her general condition; her face, however, became swollen on one or two occasions, and appeared puffy, as also did the upper and lower extremities. The urine slightly improved in appearance, and the numbers of the Filariæ in it as well as in the blood diminished; in the latter especially, at all events, the numbers obtainable by pricking the fingers or toes certainly decreased; and eventually, out of half-a-dozen or more slides not more than one or two Hæmatozoa could be detected: on a few occasions several slides were examined without any being found.

The patient, however, could not be persuaded to remain longer in hospital: indeed, all patients thus affected soon get tired of being treated for their complaint, as there is seldom any great suffering which the patient can directly connect with this condition, and often no other very well-marked symptom, beyond general debility.

As all the female patients suffering from Chyluria, brought to my notice, had been under middle age, and the disease had seemed somehow to bear a sort of ill-defined relation to pregnancy or nursing, I was glad of the opportunity of examining a woman who for some ten years had ceased to menstruate: for this opportunity I am indebted to Dr. Charles Macnamara. The woman was a housekeeper, aged 52, the mother of six children, of whom two are living. She first observed her urine to present a milky appearance four years ago; the disease came on suddenly, and lasted about a month. It reappeared without any preliminary symptoms a year and a half afterwards, and again during the summer of 1873. A drop of blood, obtained by pricking one of her fingers, was distributed over some half-a-dozen glass slides, and forthwith examined, the result being that two out of the six preparations contained specimens of the Filariæ; so that in women also, other than child-bearing disturbances may determine an attack of Chyluria. Dr. Macnamara informs me that he knows of a little girl, quite young, who is subject to similar attacks.

The most remarkable case which has come under my notice, in which the blood was affected in this manner, was that of a patient in one of Dr. Ewart's wards, whom he kindly placed at my disposal for observation and treatment. The man was an East Indian (with more of the habits of the native than of the European), about 22 years of age; he had been for about five years employed as cook on board one of the light-ships lying at the entrance of the Hooghly, spending only about three months of the year with his family on shore.

The prominent symptoms in this case were, extreme and persistent milkiness of the urine, which coagulated with great rapidity after being voided. On being heated the smell given off at first corresponded exactly with that of warm milk, but when the heat was continued for some time, was gradually replaced by the ordinary

smell of urine. This condition came on *suddenly* about two months previous to his admission into the General Hospital.

He dates his illness, however, as having commenced about a year before, for his sight then became affected, and there was "inflammation" of both eyes, together with a copious discharge of fluid from them. These symptoms have persisted, although he thinks that they have somewhat subsided since the change occurred in his urine. He has well-marked "granular lids," the mucous membrane of both the upper and lower lids are red and swollen, and the sclerotic conjunctiva injected, the vessels being large and tortuous; there is also considerable opacity of the cornea. He presents a somewhat emaciated appearance, although his appetite had always continued good, and certainly since his admission into hospital the man has gladly availed himself of the most liberal scale of diet allowed.

This is not surprising when the amount of fibro-albuminous matter, which is constantly being drained from his system, as evidenced by the state of the urinary secretion, is taken into consideration, and when to this is added the fact that no matter at what portion of his body the circulation is tapped with the point of a needle, numerous active, well-developed Hæmatozoa are invariably obtained: on one occasion I obtained as many as twelve of these creatures on a single slide. As the drop of blood from which this slide had been prepared sufficed for the preparation of two or three other slides (which, however, between them did not contain more than half-a-dozen Filariæ), the number infesting his whole body may be imagined.

A rough calculation may very readily be made; the weight of the man is 100lbs.; if the amount of blood be taken as being on the average "not less than one-tenth of the weight of the body" (Huxley), and it is assumed that each drop or grain rather contains, say, two Hæmatozoa, it would be but a reasonable estimate to set down the number as 140,000! It must, however, be borne in mind that the Hæmatozoa may be more or less localised to the capillaries and smaller vessels, which would materially modify this estimate, still I know of no fact which warrants any such assumption.

The urine also contained numerous Filariæ, but they were by no means so plentiful in this fluid as the condition of the blood might have led one to expect. I have seen them far more plentiful in the urinary secretion of a person whose blood did not appear to be infected to anything like the extent to which this man's had been.

On several occasions I attempted, but in vain, to detect the Filariæ in the copious slightly milky secretion constantly welling out of the corner of his eyes, and which in a slight degree appeared to curdle. I feel convinced, however, that could a sufficient quantity of this secretion be accumulated, they would be discovered.* Microscopically

* Since this portion was in type the inference above made has proved to have been correct, as I have obtained a specimen of the Filariæ in the midst of a shred of flocculent matter, which had been transferred from the inner surface of one of the lower eye-lids on to a glass slide, for examination.

Its breadth was $\frac{1}{7800}$ of an inch, and its length $\frac{1}{150}$", the relative proportion between the latter and the former being, therefore, as 1 to 52.

the discharge consisted of clear fluid, with numerous granular cells, precisely as observed in the urine of persons suffering from Chyluria. The reaction of the fluid was slightly alkaline.

Since the foregoing was published, I have for more than a year watched the progress of this patient. The number of Filariæ obtained by pricking his fingers and toes gradually diminished, until eventually it was only with considerable difficulty that a single specimen could be thus obtained. On the last occasion (December 1873) I failed to detect any, although several slides were examined; but, in marked contrast to its former condition, the urine contained a great number—far more so than on any former occasion. The opacity of the corneæ has become so extensive as seriously to interfere with vision—both pupils being almost invisible; he was also suffering from a recently

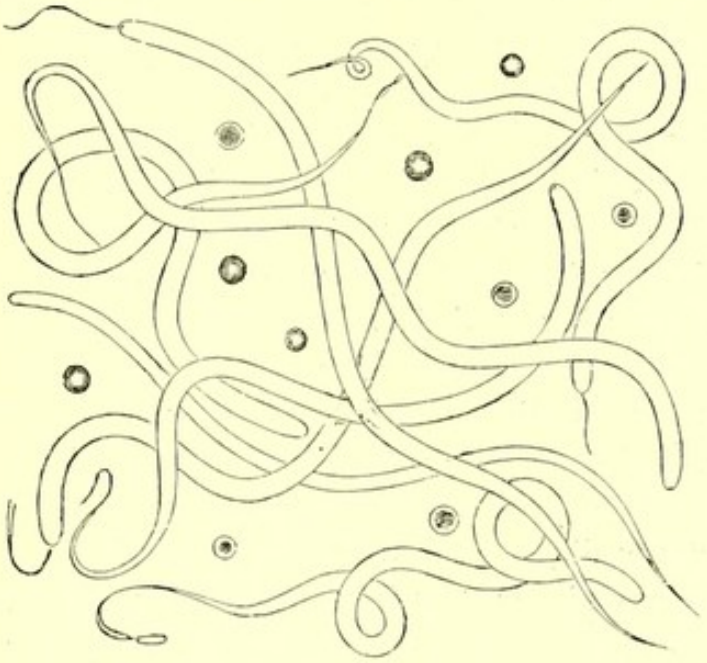


Fig. 31.—Living Hæmatozoa observed in a single preparation of blood obtained by pricking (with a needle) the finger of a European woman suffering from Chyluria.

A few red-blood corpuscles have been introduced to show the relative size of the Filariæ. ×300.

formed hydrocele. He is now unfit for work, and considerably more emaciated than he was a year ago: he has, however, had an addition to his family on two occasions within this period; mother and children "doing well."

Before alluding more minutely to the appearances presented by the Hæmatozoon, I will refer to one other case for the opportunity of observing which I am again indebted to the Principal of the Medical College, under whose care the patient was. She was the wife of a police sergeant, 30 to 35 years of age, born in this country, but of pure European parentage. Towards the end of July 1872, she was admitted into hospital suffering from a Chylous condition of the urine, with frequently recurring attacks of Hæmaturia.

The disease made its appearance two months after child-birth, 16 years ago, when

she was living a few miles from Calcutta—at Hooghly. It continued for six months, and in her opinion was cured by taking an infusion of the seed of an aromatic plant used by the natives for flavouring curries, called "*kahlajeera*," a species of Nigella (sativa ?).

In the following year she was again confined, but the symptoms did not return; in 1859, whilst residing at Rajshahye, the disease reappeared. She was then neither pregnant nor nursing. In three and a half months the symptoms subsided, the above-named native remedy having been administered as before.

Since this period she has given birth to two more children, the last child having been born in 1864; but no symptoms of her complaint had appeared until within a few days of her admission into Dr. Smith's ward, when they came on suddenly after a lapse of eight years. During the first three weeks of her stay in hospital no marked alteration in her condition was observed, neither for better nor for worse—Hæmatozoa were persistently present in her blood, no matter from what portion of her body the fluid was obtained; they were also present in the urine.

Dr. Smith tried muriate of iron, gallic acid, as well as numerous other remedial agents, mineral and vegetable, not omitting the "*kahlajeera*," in which she had much faith; but none of them seemed to produce the slightest effect. The proportion of blood in the urine increased, painful diarrhœa set in, with rapid emaciation, and she died about six weeks after her admission.

It was with considerable difficulty that permission was obtained to make a *post-mortem* examination, which had moreover to be so hurriedly performed, that Dr. McConnell, the Professor of Pathology, was unable to give me notice; but he has most kindly placed at my disposal the careful notes which he made of the appearances presented by the various viscera (fourteen hours after death), a summary of which is here given.

The brain was soft and somewhat anæmic; otherwise there was nothing special to be observed in its structure, nor in its ventricles. The right side of the heart contained small semi-decolorised clots, as also did the left auricle, but the ventricle was empty. There was some thickening of the mitral valve, and slight, irregular thickening of the lining membrane of the aorta; further than this there seemed to be nothing abnormal. The mucous surface of the trachea and bronchi appeared to be healthy. Scattered throughout the whole of the right lung were numerous specks of what appeared to be softening tubercule, each about the size of a pea; in addition to which two circumscribed cavities, one of the size of a hen's egg, the other about half that size, were found in the substance of the middle lobe; each cavity was lined by a distinct "pyogenic membrane" and contained thick muco-pus. The left lung contained a few small, irregularly distributed nodules of softening tuberculous matter, and one cavity, the size of a pigeon's egg, filled with muco-pus. The weight of the right lung was 5 ounces and six drachms, and that of the left was 8 ounces and 4 drachms.

The mucous membrane of the stomach was of a bright pink colour, not altered in

consistence, whereas the mucous surface of the duodenum presented a mammilated and congested appearance. The jejunum and ileum in the upper half were healthy, but in the lower half of the latter the Peyer's patches were prominent, and the surface covered with minute ulcers; the glandules infiltrated with a yellowish-white, soft, tubercular-like substance; the edges of the ulcers thickened and containing similar yellowish-white granular matter. The lining membrane of the cæcum and ascending colon was of a bright pink colour, and exhibited five or six circular ulcers about the size of half a pea, with raised and opaque white edges. The entire contents of the intestines consisted only of about a couple of ounces of a pea-soup-like fluid. The mesenteric glands were unaffected,

The liver was soft and fatty, otherwise normal in appearance; no reaction with iodine. The gall-bladder was almost empty, containing only a little thin ochre-coloured bile. The spleen seemed to be healthy, as did the uterus and ovaries; the former was small and unimpregnated. The kidneys presented nothing abnormal to the naked eye; the right and left weighed respectively 3 ounces 4 drachms and 3 ounces 6 drachms: these, together with the super-renal capsules, were placed in spirit and kindly forwarded by Dr. McConnell for my examination, the result of which will be referred to further on (page 519).

As in other cases of Chyluria on record, so in this, not the remotest clue is afforded as to the nature, or as to the cause, of the disease by the *post-mortem* appearances visible to the naked eye; nor is there any sufficiently-marked lesion to account for the condition of the urine during life, nor for the rapid manner in which the patient ultimately succumbed.

In order to detect the Hæmatozoon during life, the method adopted by me is as follows:—A piece of narrow tape is coiled tightly round the end of one of the fingers or toes, so as to produce a little temporary local congestion of the part, but not to such an extent as to cause the slightest pain; and with a clean, finely-pointed needle the finger is gently pricked—half-a-dozen slides and covering glasses having been previously prepared. The drop of blood thus obtained will suffice for several slides, but I find it a good plan to squeeze out only a very small drop, and transfer it altogether to one slide by drawing the edge of the covering glass along the tip of the finger so as to *scrape* off the "droplet." The glass is then carefully pressed on to the slide by a gliding motion, in order to produce as thin a layer of fluid as possible, and to ensure that all the fluid removed is retained beneath the cover, because there is a tendency on the part of the fluid to carry the Hæmatozoa towards the edge of the slide, just as is observed to take place in examinations of the urine for "casts" of the kidney-tubules.

The slides are now to be carefully and systematically examined; a lateral and horizontal stage-movement being very useful for this purpose, as it enables us to make sure that every part of the preparation has been scrutinized.

It must not be supposed that the Filariæ are to be detected by taking a mere peep through the microscope; sometimes, certainly, I have observed one, or two even, in the first field examined; but this is by no means usual, and their detection often demands considerable patience. Each slide will require about a quarter of an hour before it can be satisfactorily explored; any one who imagines that they can be detected with the same ease as a white-blood corpuscle had better not make the attempt.

Several slides may have to be examined, and it may be necessary to make a fresh puncture, for I have found the Hæmatozoa to be absent in several slides obtained from one finger, but present in all the slides obtained from another at the same time; whereas on making a fresh puncture in the finger where none had been found at first, it was ascertained that they were equally numerous in both. This is possibly accounted for by the little orifice made having become plugged by fat, etc., so that the blood squeezed through had to some extent been filtered, for although this microscopic Filaria can pass through any channel permeable to a red-blood corpuscle, still, when it is considered that the length of the former is nearly fifty times its diameter, the wonder is that they are not more completely prevented from escaping through so fine an orifice even when perfectly patent.

The search should not be undertaken with too high a magnifying power, but it should be sufficiently high to define the outline of a red-blood corpuscle quite distinctly. I have found that a good two-thirds of an inch objective answers the purpose of a *searcher* admirably; it embraces a tolerably large area so that the preparation can be examined in a comparatively short time; but care should be taken to keep the fine adjustment screw constantly moving, so as to examine the deeper as well as the superficial layer of fluid in each field as it passes under observation. Should anything unusual be observed, the low power must be replaced by a $\frac{1}{4}''$ or, better, a $\frac{1}{8}''$ objective.*

In order to keep the active Hæmatozoon under observation for some hours, a camel-hair pencil, dipped in a solution of Canada-balsam, or mastic in chloroform, should be passed along the edges of the covering glass, so as to prevent evaporation and the formation of air spaces in the preparation.

The appearance presented by the Hæmatozoon when first seen among the blood corpuscles, in the living state, will not readily be forgotten, and cannot possibly be

* It may seem superfluous to draw attention to the similarity which exists between some vegetable fibres and some of the miscroscopic "Filariæ," when the latter are not alive; nevertheless a very good objective is frequently required to distinguish them with certainty, as any one may prove for himself by subjecting the torn fluffy edges of a piece of blotting-paper to miscroscopic examination. Filaria-like fibrils will frequently be found.

A mistake of this kind is referred to by Leuckart as having occurred quite recently. A paper was published announcing the discovery of a Filaria-like Mematode in the intestines, blood and tissues of a patient, which was expected to prove as dangerous to life as the Trichina spiralis. These parasites subsequently proved to be nothing more than vegetable hairs!—"Die Menschlichen Parasiten," Vol. II, part 1, p. 151.

mistaken for anything else. The remark made by a young Bengalee student on my requesting him to look into the microscope and tell me what he saw—"He is an incompletely developed *snake*, evidently very young, though very active"—so aptly describes the object as thus witnessed, that I feel sure that any one seeing the Hæmatozoon alive will not fail to be struck with the accuracy of the quaint reply.

During the first few hours after removal from the body, the Filaria is in constant motion, coiling and uncoiling itself unceasingly, lashing the blood corpuscles about in all directions, and insinuating itself between them. It is not at rest for a single moment, and yet on one slide it appears to make but little progress, and it may frequently be watched for an hour in the same field without once giving occasion to shift the stage of the microscope. No sooner has it insinuated its "head" amongst a group of corpuscles than it is retracted, and probably the next instant the "tail" will be darted forth and retracted in a similar way.

One moment it may appear to possess a long "tail"—a fourth or more of its entire length, which follows it through the fluid like a string, whereas the very next moment not a trace of the "tail" can be seen even with the highest powers. The same phenomena can be observed to take place at the thicker, cephalic end, but with more difficulty. As usually seen, this presents a blunt or slightly tapering termination, but every now and then a fine point like a fang appears as if darted straight forward out of its substance; the next instant the creature may jerk its "head" on one side and the "fang" becomes bent and drawn after it like a ribbon (Fig 31, page 509).

As seen with a $\frac{1}{4}$" objective, these Hæmatozoa can scarcely be said to present a granular aspect. When only recently withdrawn from the body, they look smooth and almost translucent; the larger specimens, however, frequently present an aggregation of granules towards the junction of the middle with the lower half, as may be seen represented in a few of the specimens delineated (Fig. 31). Occasionally also a bright clear spot is observed at the thicker extremity extremely suggestive of an oral aperture; this likewise is represented in some of the figures in the woodcuts.

They will continue thus active under a covering glass, hermetically sealed, for from 6 to 24 or 30 hours; and if a drop of blood be suspended from the centre of a covering glass and fixed to a ring of wax, thus forming a closed cell, the Hæmatozoa may live for three days, perhaps longer, but this is the longest period during which I have known them to retain their activity.

It must not be inferred that the group of Hæmatozoa depicted in this woodcut (Fig. 31) represents *one field* of the microscope, but only that the particular specimens were observed on a single slide. The same remark applies to the second group depicted; except, that two of the figures in it represent Filariæ found in other preparations obtained from the same individual.

In the later periods of their existence the movements of the Filariæ become much slower, and the plasma of their bodies more and more granular until eventually all signs of activity disappear, and they are seen stretched or slightly curved in the field of the microscope, having lost the snake rather than worm-like appearance, which, from their tenuity and incessant coiling or wriggling movements, they had presented during life (Fig. 32, below).

If a little spirit, or other preservative agent, such as corrosive sublimate or carbolic acid and glycerine be not added, their outline among the blood corpuscles will become indistinct, and they will degenerate into mere shrivelled strings of a granular appearance, no longer recognisable as Filariæ.

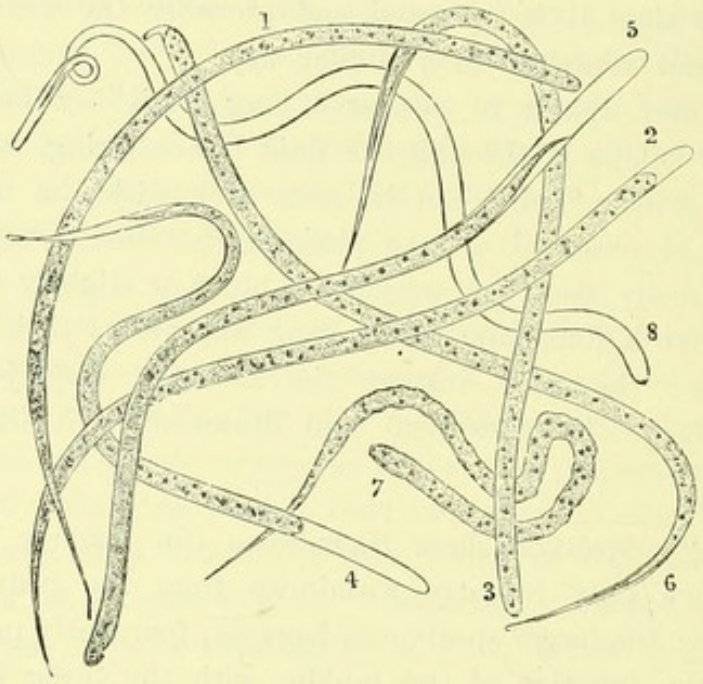


Fig. 32.—Hæmatozoa as in Fig. 31, after the addition of preservative media. ×300.
Nos. 1 to 6. Preserved in weak spirit.
(When the Filariæ are observed in slightly decomposed urine they present the appearances here shown also. Specimens 1 and 4 are specially referred to at pages 516, 517.)
No. 7. Puckered condition produced at first by the addition of pure glycerine.
„ 8. Killed by exposure to the fumes of osmic acid.

Some of the various aspects presented by them after death are delineated in the above woodcut. In No. 1 of the above woodcut the Hæmatozoon presents a granular appearance throughout its entire length; but in No. 2, a hyaline membrane is seen to extend beyond the head extremity, and in No. 3 this transparent membrane appears as if it were a continuation of the tail; whereas in No. 4 it extends beyond them both. In No. 5 the membrane appears as if slightly wider at the "tail" end, but is absent at the opposite extremity, and in No. 6 the membrane is bent in the form of a hook. In No. 7 it is seen puckered, on account of the addition of a thick fluid—when examined after such treatment by a higher power, the outline of a membrane becomes clearly evident opposite the constricted portions of the worm. The meaning of all the different

appearances presented by these Filariæ, obtained from the same patient, will become evident on perusal of a succeeding paragraph.

One of the Hæmatozoa in this woodcut (No. 8) is seen to have preserved the appearance presented during life, it having been instantaneously killed by holding the slide over the fumes of osmic acid—by far the best method I know for preserving the specimens. The blood should be quickly but evenly spread over the covering glass, forming as thin a layer as possible; the cover is then to be quickly inverted (before coagulation sets in) over the mouth of a phial containing a 2 per cent. aqueous solution of this chemical. When the preparation has turned somewhat brown, remove it and place it on a slide, previously charged with a drop of a saturated solution of acetate of potash or soda, when it is ready for mounting, and will keep, I believe, for an indefinite period.

To account for the various appearances presented by these Hæmatozoa before and after death, which have been just described and figured, may possibly puzzle others as it certainly puzzled me for over two years, although I was constantly in the habit of examining specimens; but, until their existence in the blood had been discovered, by far the greater number of them had been dead, or nearly so, before they came under observation. Having observed that the appearance usually presented by the Hæmatozoa, when recently withdrawn from the circulation, differed considerably from what was observed after or shortly before death, it was determined to watch these changes from beginning to end, and to note them as they occurred. With this object in view, a specimen, which appeared to be well developed, was selected out of several found on a quite recently prepared slide, a carefully corrected immersion $\frac{1}{8}''$ object-glass was employed, and the examination continued for eight consecutive hours.

At first the movements of the Hæmatozoon were so rapid that little could be detected in addition to what has been quite as distinctly seen with $\frac{1}{4}''$ glass, except that in certain positions assumed by the worm, and in certain lights, extremely fine transverse striæ were observed quite distinctly. The existence of these striæ had, on several occasions, been more than suspected under the lower power ($\frac{1}{4}''$), but they could not be satisfactorily demonstrated. No attempt has been made to represent those fine markings in the woodcuts as seen by such a comparatively low power as this, for it would only tend to mislead; to cut lines in wood only $\frac{1}{2500}$ of an inch apart (which is about the distance between the markings), when simply magnified 300 diameters, would be impracticable, and even in the engraving, which represents the object as magnified by twice this power, the distinctness of these markings is considerably exaggerated (Fig. 33, page 516).

As the movements of the Filaria became a little slower, it was seen that the striæ were not on its outer coat, but confined to the body of the worm, and that the tail, which almost always under the $\frac{1}{4}''$ objective looked like a lash, was not so in reality, but that, every now and then, it could be seen flapping against the corpuscles like a fin—sometimes vertically, sometimes horizontally, and then becoming folded upon itself

like a ribbon (Fig. 33, 1)—a condition which I had already observed and figured two and a half years ago without knowing what it was. Precisely similar phenomena were observed to occur at the opposite terminal extremity (Fig. 33, 2).

It was, however, only after the lapse of fully five hours' careful watching, the activity of the Hæmatozoon having considerably subsided, that the real nature of what appeared to be the rapid protrusion and retraction of the delicate membrane at the oral and caudal terminations were discovered. An unusually long tail was seen to be trailing after the "body" of the Filaria for several seconds, and whilst thus being dragged, fortunately it remained exactly in focus, when suddenly the ribbon-like folds were straightened by the darting of the pointed extremity of the worm into the very tip of this hyaline filament (Fig. 33, 2). Scarcely had this taken place than the tail was again retracted and the ribbon-like appendage became evident once more; whereupon the ribbon-like filament at the other extremity was suddenly straightened in a similar manner and the "head" rapidly projected into the very tip.

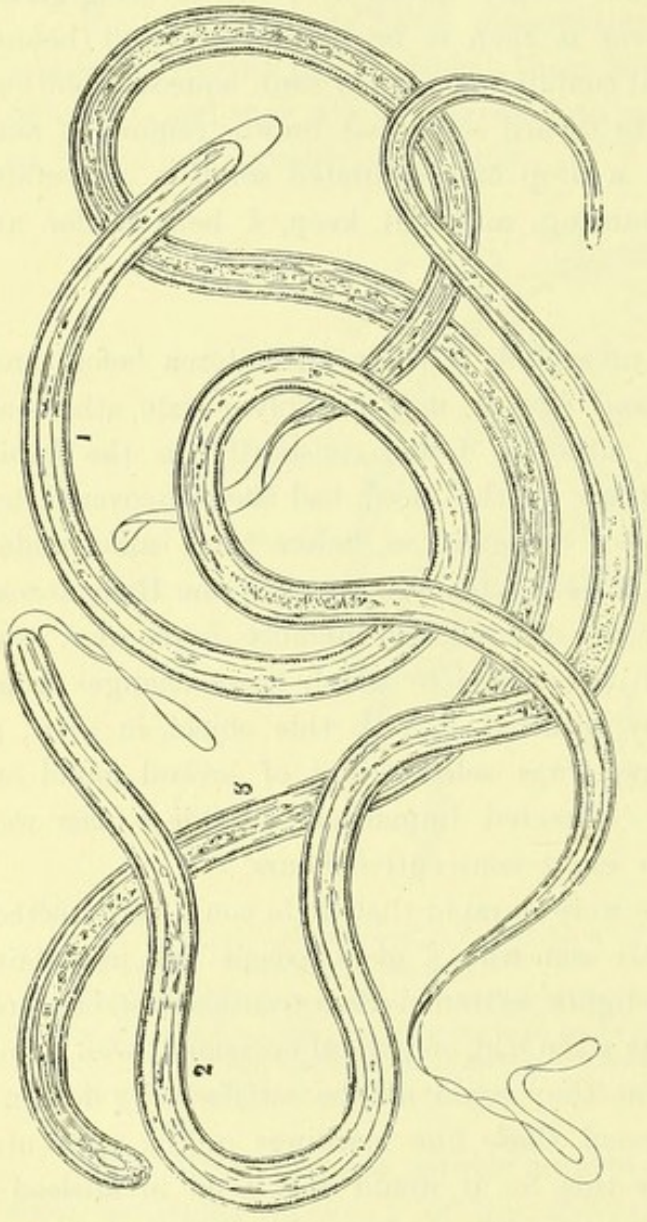


Fig. 33.—Various Appearances presented by a single Hæmatozoon, as observed under a $\frac{1}{8}$″ immersion object-glass. × 600.

It may be observed that, in the specimen marked 1 in the thirty-second woodcut (page 514), no indication of its being enclosed in a capsule is evident. This is frequently the appearance presented by specimens mounted under a fixed covering glass, especially where, as is usually the case, the field is crowded with granular or molecular matter, which so encroach upon the preparation, that the delicate filament formed by the collapsed tube can rarely be distinguished under such circumstances. This tubular envelope is, however, *invariably* present, and may always be demonstrated when the field is cleared of *débris* and slight motion communicated to the specimen so as to disengage the free end of the tube, should it be folded back upon the body of the worm, as it very frequently is; or should the Filaria have been so distended at death as to occupy the entire tube, the addition of a fluid differing in density from that in

which the preparation is placed, will generally cause a separation between the sac and its contents, as was actually produced in the specimen marked 4 in the same woodcut.

The Hæmatozoon may, therefore, be said to be enveloped *in an extremely delicate tube, closed at both ends*, within which it is capable of elongating or shortening itself. This envelope, like the sarcolemma of muscular fibres, is without any visible structure, is perfectly transparent, and, but for the difference between it and the fluid in which it is immersed in its power of refracting light (which allows of its margins or folds being brought into view), and for the phenomena so strikingly evident when the Filaria alters its length, its tubular character could not be demonstrated.

The fact of its being thus enclosed seems to show that in the present stage of its existence, the "home" of this Filaria is in the blood; it has no visible means of perforating the tissues: moreover, although constantly observed to be in a state of great activity, it does not seem to manifest any special tendency to migration, and is apparently dependent on the current of the blood for its transference from place to place; its movements, therefore, within this enveloping tube appear to be as limited as those of any other animal enclosed within a sac.

As has been already stated, a short chain of aggregated molecules, probably representing the rudiments of an intestinal canal, is frequently seen towards the centre (Fig. 33, 1), but the rest of the entire length is at first uninterruptedly clear, although not transparent. But during the time the details described in the preceding paragraphs were observed, and they became more and more evident as the activity of the Hæmatozoon diminished, the appearance throughout became granular or rather molecular. A bright spot also became very evident at the terminal point of the anterior portion, which, as already remarked, is extremely suggestive of an oral aperture, and immediately below this a somewhat elongated vacuole. From this downwards, until about the junction of the middle with the lower third, or perhaps a little nearer the middle, a more or less clearly differentiated œsophagus (?) became likewise discernible, and appeared to have a cæcal termination; but beyond this, until the caudal extremity was reached, the continuation of the digestive tract was less clearly defined (Fig. 33, 3).

It then became too dark to continue the observation, and by the next morning the Filaria had become uniformly molecular, all appearances suggestive of internal organs having vanished, although it still continued to coil itself languidly amongst the blood corpuscles.

Such is the minute anatomy of the Hæmatozoon as far as I have been able to make it out. What has here been recorded has now been repeatedly observed, and may be observed by any one possessing a good $\frac{1}{8}''$ or $\frac{1}{12}''$ immersion lens and a microscope provided with good arrangements for illumination. The simple detection, however, of the Hæmatozoa, when present in the blood, is simply a question of patience, and not dependent on any special perfection in the magnifying powers employed.

The average diameter of the Hæmatozoon, as usually found, is, as already stated, about that of a red-blood corpuscle, and its average length about 46 times that of its greatest width; that is to say, its greatest transverse diameter is about $\frac{1}{3500}$ of an inch, and its length about $\frac{1}{75}$th of an inch. These are about the measurements most frequently met with, but I have occasionally seen specimens not more than half this size. The largest specimen which I have measured was found to be slightly over $\frac{1}{3000}$th of an inch in width, and about $\frac{1}{68}$th of an inch in length, whereas the smallest was only $\frac{1}{1000}$th of an inch in width and $\frac{1}{125}$th of an inch in length: the relative proportion between the length and the greatest width being as 1 to 45 in the largest and 1 to 56 in the smallest; the width therefore gaining somewhat in proportion to the length as the total dimensions increase.

From what has been above stated concerning the power of extension and contraction possessed by the Hæmatozoon, it will be perceived that these measurements are subject to variations during life; and, as death may occur when the Filaria may happen to be in either of these conditions, the relative proportion between the length and breadth may then also be found to vary somewhat.

In order to prevent misconception, it may perhaps be well to compare these measurements with those of two well-known Nematode helminths which are occasionally found in the tissues of the human body, *viz.*, the Muscle-trichina and the Guinea-worm, or rather its contained embryos. Both of these parasites present a certain degree of likeness to the Filaria described in this paper. The first-named is found in the muscular tissue; the second in the cellular tissue; and the third in the blood. All three present transverse markings, more or less evident; in the Guinea-worm embryo they are particularly distinct; but beyond this feature the similarity between them appears to cease.

They differ from each other in size, in form, and in the relative proportions of length to breadth—setting aside altogether the great difference which exists between their minute internal organisation.

As to size and form the Hæmatozoon approximates more closely to the Filaria medinensis or Guinea-worm embryo, than to the larval stage of the Trichina spiralis, though much smaller than either, especially in breadth. The average length of samples of the former which I possess is $\frac{1}{22}$nd of an inch, and the breadth $\frac{1}{1000}$, so that the breadth to the length is as 1 to 31: whereas the specimens of Trichina, with which these comparisons were made, averaged $\frac{1}{25}$th of an inch in length and $\frac{1}{700}$th in width; so that they are only 28 times the length of their greatest transverse diameter. It will be remembered that these proportions in the case of the Hæmatozoon have been referred to as being on the average 1 to 46.

A still greater dissimilarity between these helminths than the disparity in size and relative proportions, is the totally different aspect presented by their anterior and posterior extremities; this is sufficiently evident without referring to the minute

structural anatomy of the parts. The cephalic end of the Trichina is almost pointed, and its caudal termination blunt; whereas, although the anterior extremity of the two Filariæ agrees in the matter of being somewhat rounded, and the posterior end in both comes to a very fine point, nevertheless, the relative proportion between the tail of the one and that of the other is sufficiently great to present a marked difference—the tail of the Dracunculus being nearly $\frac{1}{3}$rd, whereas that of the Hæmatozoon is not, at the utmost, more than $\frac{1}{8}$th of the entire length. Of course this is exclusive of the hyaline tube within which the latter is enclosed. Possibly when live young Dracunculi shall have been as carefully examined and described as the lifeless specimens have been by Mr. Busk and Dr. Bastian, the similarity between the Filariæ will become more evident.*

The comparisons just instituted between the three helminths referred to will, perhaps, be more clearly understood by throwing these details into a tabulated form: †—

	Average Breadth.	Average Length.	Relative Proportion of Breadth to Length.	Aspect Presented by		Relative Length of Tail to Total Length.
				Head.	Tail.	
Trichina (of muscle)...	$\frac{1}{700}''$	$\frac{1}{25}''$	1 to 28	Pointed	Blunt	.....
Dracunculus (embryo).	$\frac{1}{1000}''$	$\frac{1}{32}''$	1 to 31	Rounded	Acutely pointed	1 to $3\frac{1}{2}$
Human Hæmatozoon...	$\frac{1}{3500}''$	$\frac{1}{75}''$	1 to 46	,,	,,	1 to 8

The part which the Hæmatozoon appears to take in the production of disease will become still more evident when the condition of the kidneys and supra-renal capsules, referred to in a previous paragraph (page 511) as having been obtained from a patient who died of Chyluria, has been described.

To the naked eye none of these organs presented any marked deviation from the normal standard, except that the kidneys were more than usually lobulated, and, that on section several of the pyramids, especially near their apices, presented a smooth, tallowy appearance, suggestive of amyloid disease. No approach to the characteristic iodine reaction could, however, be obtained; but when longitudinal

* Since this paragraph was in type, I have, however, had ample opportunity of satisfying myself on this matter by the examination of numerous young Dracunculi in all stages of development obtained from a patient suffering from Guinea-worm, admitted into the General Hospital under the care of Dr. Coull Mackenzie; but I find that there is even less resemblance between the Filariæ during life than was suggested by lifeless specimens.

† The measurements here introduced of the young Trichinæ and Dracunculi do not materially differ from those generally given. For the sake of uniformity, however, it was considered advisable to measure all three with the same micrometer-scale.

sections were subjected to microscopic examination, numerous translucent oil-like tubules of a somewhat varicose appearance could be observed running alongside the uriniferous tubes as if the lymphatics or minute blood-vessels of the part had become plugged. These sections, when placed in boiling ether, and afterwards subjected to prolonged maceration in it, did not appear to be materially affected by the process —the translucent oil-like tubules being quite as evident as before.

No other morbid changes could be detected as having taken place in either the tubular or cortical tissue of the kidneys, but in every fragment, no matter from what part of the kidneys removed, numerous microscopic Filariæ were invariably obtained, if the tissue had been properly teased, precisely analogous to those which had been detected in the blood and in the urine during life. Teased fragments of the supra-renal capsules yielded similar specimens. On slitting open any portion of the renal artery, from its entrance into the kidney as far inwards as I was able to follow its ramifications, and gently scraping its inner surface with a scalpel, numerous Hæmatozoa could always be obtained. The renal vein when similarly examined also yielded specimens of the Filariæ, but they did not seem to be so numerous in it.

The vessels themselves did not appear to be diseased, and such of the branches as could be seen with the naked eye did not strike me as being abnormally large. But whether the microscopic ramifications and the capillaries were distended or otherwise (in the absence of properly injected preparations of the organs) could not well be ascertained.

Having traced the course of the Hæmatozoon from the blood through its channel into the urine, the peculiar appearances presented by this secretion will now be very briefly considered.

The chemical constitution of Chylous or milky-urine is so well known that it is not necessary to do more than refer to the principal features which it presents. It is, as the term applied to it conveys, more or less perfectly white, has a faint odour of milk, which is heightened by warmth; and, like that secretion, may be passed through several layers of filtering paper without materially modifying its colour. Usually it is of low specific gravity—from 1006 to 1018—and manifests a slightly acid reaction to test paper. As a rule, the more it approaches the appearance of milk, the more readily and firmly does coagulation take place. When the presence of blood is a prominent feature in it, curdling takes place still more perfectly, but the early addition of solutions of ammonia, sulphate of soda, or nitrate of potash retards if it does not completely prevent this change; frequently, however, the process has already commenced before the escape of the fluid from the bladder.

The elaborate analyses which have from time to time been made of the urine in this condition, as well as such simple analyses as I have been able to conduct,

have not tended to show that there is any organic or inorganic substance in the secretion, but what already exists in the nutritive fluids of the body, or that any new *chemical* combination has been called into existence. With regard to the alleged presence of sugar in this kind of urine, my attempts to detect it have been entirely negative.

In short, the urine appears merely to deviate from the healthy standard in so far that it contains an abnormal amount of fatty and fibro-albuminous material, with, perhaps, a diminution in the percentage of urea; in connection with this, however, I may add that in the cases noted, which presented a low specific gravity (1006—1010), the quantity voided had been considerable, from 60 to 70 ounces in the course of the 24 hours.

On no occasion have I been able to detect "casts" of renal tubules in urine of this nature, even in cases where previous attacks of the malady have occurred.

When subjected to microscopic examination, this kind of urine presents a finely molecular appearance; when recent, however, scarcely any distinct oil-globules, such as are constantly observed in milk, are present; but when acetic acid is added, followed by a little warm ether, this "molecular base" becomes replaced by large globules of fat, which may be seen to form whilst the re-agents are being applied. In the meshes of the coagulated substance numerous granular cells are seen, apparently identical with those of chyle, lymph, or the white cells of the blood; and, generally, a sprinkling, more or less marked, of red-blood corpuscles.

Besides these, if the shred of coagulum on the slide has been properly "teased," the Filariæ, described in the preceding pages, will also be usually found. However, they may not be present in *every* sample of chylous urine examined, or, rather, it would, perhaps, be more correct to say, the numbers present may be so few as to elude detection.

With regard to the size of the Filariæ which are met with in the urine, it may be observed that they present the same measurements as those met with in the blood; some of the largest as well as some of the smallest examples have been found in this secretion.*

The importance of bearing in mind the difficulty that is sometimes experienced in discovering the Filaria in the urine also, may possibly be more strongly impressed by the narration of an illustrative case, which will, moreover, serve to draw attention to other important matters bearing on the question of infection with Hæmatozoa:—

A European, aged 38, formerly in the army, was kindly sent to me by Dr.

* I have not succeeded in satisfying myself of having obtained distinct Ova on any single occasion, although some hundreds of preparations of Chylous urine have been examined; the sediment of a large quantity of this fluid having been collected and preserved for the purpose. Ova of various insects are, not uncommonly, found in urine of this character, even when it has been set aside for only a short time, and ova-like bodies have frequently been distinguished, but hitherto they have all been rejected as merely accidental occurrences.

McConnell, with a note stating that the man was amongst his out-patients, and had been suffering, and was even suffering a little still, from Chyluria. The medical history which I gathered from the man was, briefly told, as follows: Has suffered more or less constantly for five years from what he believes to be "chronic dysentery." This came on during his residence in Mysore. Eight months after the advent of the intestinal affection, he observed that the urine passed towards the middle of the day was white, but was not so in the early morning. His hearing and sight became affected about the same time, and have remained imperfect since, although there is nothing to be observed wrong about either set of organs.

The urine at the time he paid me a visit did not seem to be particularly affected, merely a little cloudy, but was albuminous. A little carbolic acid solution having been added to it, it was set aside in a conical vessel, and subsequently the sediment removed by means of a pipette for microscopic examination, This is usually the method adopted by me in cases when the fluid does not coagulate, or when, after coagulation has taken place, it has become liquefied.

Slide after slide was examined in vain, still I felt convinced that, as there had been a distinct history of Chyluria, and as the urine was still albuminous, but contained no "casts," the original cause had not entirely disappeared. Eventually, after searching for about four hours, three excellent specimens of the Filariæ were obtained, one of which I forthwith despatched to Dr. McConnell. A week afterwards the patient returned, but I failed to detect a single worm in the specimen of urine which was obtained on this occasion. He came a third time, after an interval of about another week, when Filariæ were detected in the sediment without much delay.

Several preparations of the blood were also examined, but the Hæmatozoa were not detected in this fluid. Were, however, a couple of *ounces* of the blood examined (coagulation being prevented by the addition of a neutral salt), instead of a couple of drops, doubtless the sediment would contain plenty of the Filariæ, seeing that a few must have actually passed out of it through the kidneys, as we have already seen that they are not localised in these organs, the latter simply acting as one of the channels through which they may escape out of the circulation.

I may refer to a similar experience in one other instance:—A middle-aged lady, long resident in Calcutta, was referred to me by Dr. Charles as she had for some time suffered from recurring attacks of Chyluria, which baffled all kinds of treatment. The urine which she forwarded to me was, on several occasions, decidedly chylous, and on nearly every occasion active Filariæ could be detected, but the attempts which were two or three times made to obtain them direct from the circulation proved fruitless.

The converse of this has, on one occasion, happened to me, namely, finding the Filaria

in the blood but not in the urine; as in the former instances, however, there can be little doubt but that had more patience been exercised in the search the results would not have been negative.

As the case last referred to is one of considerable interest,—Leprosy being by far the most prominent feature in connection with it,—it may be well to allude to it more fully. The urine of one of the prisoners in the Presidency Jail was, about the middle of March 1873, sent to me by Dr. Mackenzie for examination, as pus was suspected. Finding coagula in the fluid, I suspected the case to be one of Chyluria, and proceeded to the Jail hospital in order to make further inquiries, as microscopic examination of the urine had yielded only negative results. I found that the patient had been a leper for about fourteen years—the disease having come on when he was about 16 years of age, his present age being 30. His feet were swollen, cracked, and almost entirely devoid of sensibility; ulcers penetrated between the metatarsal bones of each foot; several of these bones, as well as the proximal phalanges, had become absorbed, and the corresponding toes had been retracted by the tendons in such a manner that the nails barely projected beyond the outline of the body of the foot: his hands were also affected, and altogether he presented a miserable appearance. Nothing wrong, however, had ever been observed in connection with his urine, until about a fortnight before I saw him, when it was seen to become suddenly milky and to coagulate in the vessel.

Having obtained the foregoing account of his history, I proceeded to examine several slides of blood obtained from his fingers and toes, and readily detected numerous, very active, Filariæ. As the man's sentence was just expiring, he left Calcutta for some distant village, so that his subsequent history cannot be obtained.

The phenomena associated with Chyluria are so well known that it is not deemed necessary to give more than the salient features of the malady, more especially such as are exemplified in the cases referred to in this paper, which, in the main, correspond very closely with the cases that have been from time to time recorded by others.

In the first place it is to be noted that the malady is decidedly *localised* as to its origin. As far as I have been able to ascertain, the only cases on record have occurred in persons who have at some period of their lives inhabited the East or West Indies, some parts of Africa, Bermuda, Brazil, or the Mauritius; so that all writers agree, no matter to what particular cause the disease has been referred, that it is intimately related to a tropical climate. Simple removal, however, from such climate has not sufficed to prevent a recurrence of the disease in England or in other parts of Europe.*

Secondly, it is noticeable, that the disease, as manifested by the milky appearance

* I have since observed that Dr. William Roberts, in his well-known work "On Urinary and Renal Diseases" (2nd Edit., page 318), records the history of a woman suffering from Chylous urine who had never lived out of Lancashire.

of the urine, comes on very *suddenly*, not only on the first, but on succeeding occasions also; this peculiarity to my mind points to a local cause in the system, rather than to a generally distributed functional disorder.

Thirdly, there is a complete absence of casts of the tubules of the kidney in the urine, notwithstanding the large amount of albuminoid elements present.

And fourthly, it is frequently associated with more or less distinctly marked symptoms of various other obscure diseases, such as partial deafness; diarrhœa, often very persistent; chronic conjuctivitis, or some more deeply-seated defect in the visual organs; and sometimes temporary swellings of the face or extremities.

These varied complications may, I believe, be very satisfactorily accounted for now that it has been ascertained that the nutritive channels of the tissues, even to their most minute ramifications, are inhabited by numberless living Hæmatozoa, which, accidentally or otherwise, accumulating in any particular set of these channels, may lead to local stoppages in the flow of the nutritive fluids and to rupture of the extremely delicate walls of the capillaries, lacteals, or lymphatics. The extreme activity of the Filariæ, especially should a bundle of them accumulate in one particular spot, would doubtless materially aid in giving rise to rupture; for, as is well known, the walls of these channels are extremely delicate, those of the lymphatic system being especially so. The resulting phenomena, such as the escape of the nutritive fluid and of the Filariæ contained within the ruptured channel into the excretory ducts belonging to the part, appears to me to be so simple a procedure that to dilate on its mechanism would be quite superfluous. When the fissure becomes plugged or healed these unusual symptoms naturally disappear. It would seem, therefore, that the milky appearance of the urine is merely one of the symptoms of the existence of this Filaria in the nutritive channels of the body.

It must not, however, be inferred that I would ascribe *all* cases of Chyluria to this cause, although my own experience of the disease would almost warrant such a statement, seeing that out of the seven persons whose blood was infected with Filariæ, as referred to in these pages, six were known to suffer from Chyluria; but as the history of the seventh is quite unknown, it would be useless speculating on the subject. On the other hand, on no occasion have I met with this parasite in the urine except when associated with this complaint, and here I have distinct evidence in more than twenty instances.

Doubtless a combination of various other circumstances might produce similar phenomena, just as various obstructing causes, such as the pressure of tumours, diseased condition of the vessels, etc., may produce the exudation of milky fluid on various part of the body, from the abdominal walls, the groin, the axilla, the thigh, and other parts, such as are constantly being reported in medical journals. Nevertheless, cases occurring in warm countries, or in persons who had formerly

resided in them, appear to indicate that the disease is, probably, not dependent on such mechanical or pathological causes as these.*

The same remarks apply to the etiology of the various other phenomena enumerated as the more or less frequent concomitants of Chyluria, without much modification; for even should actual rupture not take place, local congestions may be induced, or very trifling fissures, which might yet be sufficient to interfere with the functions of delicate organs, or it may be, as in the case of the eye or ear, that the mischief may be chiefly due to some changes induced in the refractive media of the former, or in the fluid in contact with the nerve filaments in the latter.

The intestinal affection, if in reality connected with the entrance or exit of these Filariæ, deserves special attention. The only *known* symptom from which the man in whose blood this helminth was first discovered, was severe diarrhœa; the commencement of the illness of another man is dated from a similar attack, which developed itself into what is described as "chronic dysentery," on which the usual medicines appear to have had no influence, for during the last five years the disease came and went without reference to medical treatment—the chylous condition of the urine having been equally irregular in its appearance and disappearance. It will be remembered that the intestinal affection commenced eight months before the urinary symptoms appeared; moreover in the woman whose autopsy has been recorded on a previous page, "tubercular like" ulcers were found in the intestines, as also in the lungs. All these occurrences, especially when taken in connection with what is *known* to occur in connection with the migration of several parasites, are too prominently associated with the history of the cases in which these Hæmatozoa were detected to permit of the subject being passed over without comment.

With reference to the "granular-lid" condition of one of the patients affected with Hæmatozoa, it has been demonstrated, since the earlier pages of this paper were in type, that not only had congestion resulted from the presence of the Filariæ, but actual rupture and escape of one of them at least occurred, either through the channel of the lachrymal, or of a Meibomian gland.

In continuation of the subject of the association of Chyluria with other diseased conditions, the following particulars obtained since the original publication of these observations may be of interest:—Towards the end of the year (1873), Dr. Ewart forwarded to me for examination a sample of whey-like urine, obtained from a man suffering from a scrotal tumour, with the request that I would state whether I considered that the fluid should be looked upon as "Chylous urine." Although highly albuminous, it did not show any tendency to coagulate spontaneously, so it was thought better to wait for more samples. Dr. Ewart very kindly took me to see his patient—a Jew—who had suffered from scrotal enlargement for many years,

* Dr. W. J. Palmer has, quite recently, published some highly interesting cases bearing on this subject in *The Indian Medical Gazette* (Vol. VIII, 1873).

but whose urine had never manifested this turbid appearance till four days previously. The urine voided in my presence was more distinctly milky, and a few coagula were observed, so it was determined to make a search for Filariæ—especially as Dr. Ewart was anxious to ascertain as far as possible whether the albuminuria was necessarily dependent on organic disease of the kidneys, the friends being very desirous that the scrotum should be operated upon. I brought away two samples of urine with me, but it required *five hours* of steady application to the microscope before a single specimen was found; specimens were however subsequently found in both samples of urine. The diagnosis having thus been satisfactorily established, the operation was carried out. Dr. Ewart promises to publish all the particulars of the case before long, as it embraces some other points of considerable interest.*

It will be observed that the foregoing case, as well as the case cited in which Leprosy was succeeded by Chyluria (page 523), bear out, in a marked manner, the importance of the inference which I felt that I was justified in drawing when this report was submitted to the Government in 1872, *viz.*, that the milky condition of the urine is to be looked upon as one of the symptoms of the presence of Filariæ in the system. I felt persuaded at that time that some of the unhealthy conditions observed among persons residing in tropical climates, especially those apparently implying abnormalities in the lymphatic system, would, at some future period, be found to be intimately associated with some such parasitic condition as this. With a view of elucidating this as far as possible, I have availed myself of every opportunity of examining all manner of fibro-albuminous exudations which have come in my way. Whilst the re-issue of this paper was being printed off, a case still more confirmatory of the opinion then expressed has come under my notice, for the opportunity of investigating which I am again indebted to Dr. Coull Mackenzie.

The patient was an East Indian, 35 years of age, had lived in India all his life, and had been in the enjoyment of fair health until about 9 months ago, when he observed that his scrotum was enlarging. He was several times tapped for hydrocele, and a more or less milky, pus-like fluid withdrawn. The scrotum eventually became extremely painful, and the swelling increased until it had attained almost to the size of his head. He was admitted into the General Hospital (for thickening and enlargement

* I cannot avoid availing myself of the opportunity which this case also affords of reiterating the fact—for I feel that it cannot be done too strongly nor too often—that the detection of Filariæ, whether it be in the urine or in the blood, is sometimes a matter of very considerable difficulty. Hours may have to be spent in examining the sediment of apparently excellent samples of Chylous urine before they are found; fresh supplies may even be required, for the numbers present may vary very much in different samples obtained from the same individual, and, as may be learnt from some of the cases narrated above, they may be even absent for a time from either the urine or the blood, or from both—at all events their detection required more patience than I was able to command at the time of examination, whereas they were obtained with tolerable ease from the same persons on subsequent occasions: I have also observed that, occasionally, they will disappear altogether for some time previous to the disappearance of the Chylous condition of the urine. It will therefore be evident that no great amount of foresight is required to be able to predict that, owing to want of proper appliances, want of time, or other circumstances, such remarks as "Filariæ were searched for but not found" will, not infrequently, be recorded in connection with reports of Chyluria cases.

of the scrotum) a few days before I saw him, and another tapping being resorted to, the fluid then removed was sent to me for examination by Dr. Mackenzie. It presented a purulent appearance, but had no offensive odour. Microscopically it consisted of broken-down granular matter, with molecules of fat. The sediment (removed by means of a pipette) contained several excellent samples of the Filaria sanguinis. Next morning the scrotum, which was now inflamed and very painful, was again pierced with a trocar and about eight ounces of a sanguineous fluid extracted. This fluid was also examined microscopically and found to consist chiefly of tolerably well-preserved red corpuscles, with an abundance of colourless granular cells. In addition to this every slide of the sediment contained some half-dozen specimens of the Filaria—presenting the usual measurements and anatomical appearances.

This case presents several points in common with the one recorded immediately before it—enlarged scrotum, together with hydrocele or hæmatocele; but the first case cited was an enlarged scrotum of very long standing, and eventually associated, for about a fortnight, with Chyluria; whereas the other case had been of short duration, and, hitherto, had not become complicated with Chyluria. In another case, recorded on a previous page (509), it will be noticed that Chyluria preceded the scrotal affection.

Although feeling convinced that Chyluria and other morbid phenomena are induced by the presence of these microscopic Filariæ in the circulation, still, unless it can be shown that they may have a prolonged existence in this condition, it will be difficult to reconcile this opinion with the fact that the malady so frequently recurs in the same individual. It seems unlikely that the same person should become re-infected with Hæmatozoa several times, and especially that re-infection should occur after years of residence in England, where, probably, this particular Filaria is not indigenous.

Not having been able to watch the progress of isolated cases for a sufficiently long period to judge whether or not all the Hæmatozoa in the system escape during a single attack of Chyluria (the period of their existence in the stage in which they are found in the blood having expired), nor having succeeded in prolonging their existence by artificial cultivation, in serum, moist sand or saliva, beyond a period of three days, it will be necessary for me to refer briefly to a few of the recorded instances of Hæmatozoa occurring in lower animals, so as to fill up the gap in the chain of evidence as far as possible.

Foremost among the recorded particulars concerning Hæmatozoa are those of MM. Grube and Delafond, which were presented in their "Mémoire" to the French Academy of Science.* These gentlemen, during a period of nine years, made observations on 29 dogs, in whose blood on an average 55,000 microscopic worms were estimated to exist. The diameter of these was somewhat less than that of a red-

* "Mémoire sur le ver filaire qui vit dans le sang du chien domestique." *Comptes Rendus.* T. XXXIV, p. 9.

blood corpuscle; the length, however, is not given in this communication, but I find this referred to in one of the early volumes of the *Lancet* (1843) as being about $\frac{1}{100}$th of an inch, which is somewhat smaller than the human Hæmatozoon. These dogs were under observation for periods varying from several months to five years, during which the state of the blood remained unchanged. *Post-mortem* examinations appear to have been conducted with great care at all seasons of the year, but on *one* occasion only were what the authors deemed to be the "parent-worms" discovered. Six of these were found to be lodged in a large, recently-formed clot in the right ventricle—four being females and two males. The size of these was by no means microscopic, being from 5 to 7 inches in length (14 to 20 centimètres),* and from $\frac{1}{25}$th to $\frac{1}{16}$th of an inch transversely. Schneider questions whether these were the parent-worms of the microscopic Filariæ;† others state that they had simply found their way to the heart from the intestines by accident, because this observation of MM. Grube and Delafond, although published about twenty years, has never been confirmed. Leuckart, who, however, expresses no opinion on this particular subject, refers to these observations as an illustration of the fact that, with the exception of the Trichina spiralis, not a single Nematode has been observed to infect its own "bearer"—the Hæmatozoa of dogs as well as of frogs never having been observed to develop into mature Helminths as long as they remained in the blood.‡

In a highly interesting paper read by Dr. Cobbold before the Linnean Society in 1867,§ it is more than hinted at that the Hæmatozoa referred to by MM. Grube and Delafond were the brood of "Spiroptera sanguinolenta" so commonly found in the heart of dogs in China, but nothing is mentioned concerning the microscopic examination of the blood of these animals. In a foot-note it is stated that Dr. Lamprey had forwarded specimens to the Netley Museum. Should these be still in a good state of preservation, it would be a great matter if Professor Aitken would re-examine the specimens, especially as to the minute structure of the contained embryos, if there be any, and publish the result.‖

As regards the blood and heart of dogs in India, out of about 300 dogs examined by Dr. D. D. Cunningham and myself in connection with various experiments, in no instance were any such Helminths detected, so that the canine Filariæ of France and China would appear not to be found in Bengal.

Dr. G. E. Dobson has drawn my attention to a description of mature Filariæ found by M. Joly in the heart of a seal; the female worm is stated to have

* Not as erroneously stated in some English works on Helminthology, "from one-half to three-fourths of an inch."

† "Monographie der Nematoden," 1866, p. 88.

‡ "Menschlichen Parasiten," Vol. II, Part 1, p. 102.

§ "Journal of Linn. Soc."—Zoology, Vol. IX.

‖ Acting on this suggestion, Dr. F. H. Welch, Assistant Professor of Pathology, Army Medical School, has made careful examinations both of the mature parasites and of their contained embryos and ova; and recorded his observations in the *Lancet* (Vol. I, 1873) and in the *Monthly Microscopical Journal* (Vol. II, 1873).

been stuffed throughout its entire length with ova and embryos; the latter measured $\frac{1}{40}$th to $\frac{1}{30}$th of an inch in length and $\frac{1}{2500}$th in breadth, but the author does not consider that they could circulate with the blood through the capillary vessels.*

Such in a few words is the present state of our knowledge of the principal Hæmatozoa affecting lower animals; and from these records alone would our nferences have had to be made in regard to the particular question as to the possible duration of the human Hæmatozoon were it not for a rather strange coincidence.

The foregoing account had just been transcribed from my notes, when I had occasion to visit the Government Printing Establishment, where, to my utter surprise, I saw, busily putting into type a portion of the foregoing pages, the very man in whose urine these Filariæ were first detected, more than two and a half years ago. Being rather below the average in intelligence, he had not the remotest idea to what the manuscript referred.

At my request he called upon me in the afternoon, and I learnt from him then, that his urine had been perfectly healthy ever since he left the hospital, about April 1870; it certainly looked healthy when he called, and was quite free from albumen.† I prepared seven slides from blood obtained by pricking the middle finger of one hand, and three slides from the same finger of the other hand. On seeing me do this, the man inquired why I had made so many preparations, as on a former occasion I had only taken *one* slide—a circumstance, by the way, which I had quite forgotten; certainly I had not discovered Hæmatozoa. This little incident also conveys its lesson; had I taken a dozen slides on the first occasion instead of one, the date of the detection of the Filaria in the blood would probably have been simultaneous with their detection in the urine. In the first four or five preparations examined nothing could be observed; in the two next taken up, one belonging to each hand, Hæmatozoa were detected, very active, but in no way differing from the excellent live specimens which I had obtained in his urine long ago, and in no way differing from the Filariæ since detected in the urine and blood, of so many persons. The measurements of two specimens were taken on the following morning after their activity had subsided; one was $\frac{1}{76}$th of an inch in length by $\frac{1}{3500}$th in breadth, and the other $\frac{1}{80}$th by $\frac{1}{3500}$th

After this I lost sight of the patient for about six months, but in March 1873 he called upon me, when I re-examined his blood and again obtained numerous Filariæ in it—exactly three years since they were first recognised in his urine. He called once more, on the 12th April, complaining of diarrhœa and pain in the epi-

* Ann. Mag. Nat. Hist., 1858, p. 400.

† On referring to my notes of this case, I find that, at the time when he left the hospital, the albumen had disappeared from his urine and that Filariæ could no longer be detected in it—the disappearance of the Filariæ preceding the cessation of Chyluria.

gastric region, and was admitted into the General Hospital under Dr. Coull Mackenzie. These symptoms passed away soon after his admission, but he became very feverish and sometimes slightly delirious; but the symptoms were not such as could be referred to any classified disease. By the 23rd he appeared to have improved, but there was a relapse on the following day, and on the 25th he became highly delirious, and died, rather unexpectedly, during the night. The hospital sergeant through some mistake gave over the body to the friends of the deceased before any intimation of his death had been made to Dr. Mackenzie, so that, unfortunately, no *post-mortem* examination could be held.

Here is, therefore, definite information more satisfactory than that to be obtained by instituting comparisons between the Hæmatozoa of man and of animals, that, not only may those found in man *live for a period of more than three years*, for certain, but that there is no evidence that they have any tendency to develop beyond a certain stage so long as they remain in the circulation. For aught we know to the contrary, these Filariæ may live for many years, and thus, at any moment, no matter how long after a previous attack, nor in what country the person may reside, he may be surprised by the sudden accession of Chyluria or any other obscure disease, such as will readily be understood by the physician when he becomes aware of the state of the blood.

If after the first brood of young Filariæ, there be no provision for other broods to follow, then every attack would be a step towards permanent recovery; but of this I know nothing at present, although some of the cases recorded appear to warrant such an inference. Nor have I any definite knowledge as to how the blood originally becomes infected; to hint that it is possible, if not probable, that the Filaria may eventually be traced to the tank—either to its water or its fish—is the utmost that can be done.

Many other interesting questions suggest themselves as matters for future inquiry; such, for example, as to whether the fœtus *in utero* is infected by the mother's blood: cases have been recorded which seem to favour such a supposition; such instances, however, may have been due to the particular localities in which the persons resided—parents and children having for generations been subject alike to the same influences. On one occasion I attempted to solve this question, but the mother, who herself was very averse to having her finger pricked, peremptorily refused to submit the child to a similar trivial operation.

This paper having considerably exceeded the limits originally intended, it may be that the leading facts referred to have become obscured by the digressions that have been necessarily made, so that, before concluding, a short summary of the observations and of the inferences which have been deduced therefrom may be advantageous:—

(1) The blood of persons who have lived in a tropical country is occasionally invaded by living microscopic Filariæ, hitherto not identified with any known species, which may continue in the system for months or years without any marked evil

consequences being observed; but which may, on the contrary, give rise to serious disease, and ultimately be the cause of death:

(2) The phenomena which may be induced by the blood being thus affected are probably due to the mechanical interruption offered (by the accidental aggregation perhaps of the Hæmatozoa) to the flow of the nutritive fluids of the body in various channels, giving rise to the obstruction of the current within them, or to rupture of their extremely delicate walls, and thus causing the contents of the lacteals, lymphatics, or capillaries to escape into the most convenient excretory channel. Such escaped fluid (as has been demonstrated in the case of the urinary and lachrymal or Meibomian secretions, and in fluid removed from an enlarged scrotum) may be the means of carrying some of the Filariæ with it out of the circulation. These occurrences are liable to return after long intervals—so long, in fact, as the Filariæ continue to dwell in the blood:

(3) As a rule, a Chylous condition of the urine is only one of the *symptoms* of this state of the circulation, although it appears to be the most characteristic symptom which we are at present aware of:

(4) And, lastly, it appears probable that some of the hitherto inexplicable phenomena by which certain tropical diseases are characterised, may eventually be traced to the same, or to an allied condition.

The importance of a careful microscopical examination of the blood of persons suffering from obscure diseases, in tropical countries especially, is therefore more than ever evident, and opens up a new and most important field of inquiry—referring as it does to a hitherto unknown diseased condition.

CALCUTTA,
January 1874.

ADDENDA.

A FEW days after the publication of the January number of the "Indian Annals," another case was brought to my notice tending still further to throw light on the etiology and pathology of the diseased conditions referred to at pages 525—527; Chyluria, in this instance, being associated with Elephantiasis of the scrotum *and of the leg.*

The patient was a middle-aged native, suffering from a second attack of Chylous urine, the attack having already lasted six weeks. The first attack came on suddenly a year previously, and was of two months' duration. The scrotal enlargement commenced six or seven years ago, but it is only since about three months that he has observed his leg increase in size—the enlargement being most marked on either side of the left ankle.

About a dozen specimens of blood were obtained from the tips of his fingers and toes, each prick of the needle yielding several specimens of active Filariæ.

Two days afterwards another native presented himself likewise suffering from

Chyluria, the third attack within the last two years, but as yet not complicated with any other disease. In this person's blood, also, Filariæ were very numerous—each slide containing two, three, or more specimens.

For the opportunity of examining the two persons above referred to, I am again indebted to my friend Dr. J. F. P. McConnell, among whose out-patients, at the Medical College Hospital, the cases occurred.

A week or so later Dr. Kenneth McLeod, Professor of Anatomy at the Medical College, very kindly forwarded for my examination about three ounces of a reddish-brown fluid, emitting a faint, but not disagreeable, odour, of slightly alkaline reaction, and with a specific gravity of 1022. After standing awhile the reddish colour matter partially subsided; the upper layer assumed a chyle-like aspect and formed an imperfect coagulum.

This fluid had exuded, through minute orifices, from soft tubercular elevations on the surface of the scrotum of a native patient. The scrotum is described as presenting a sponge-like aspect, especially on the left side, and is covered with yielding prominences from which fluid may constantly be squeezed—a condition which appears to have existed about three years. On subjecting the sediment of this fluid to microscopic examination, numerous living Filariæ were readily detected.

This adds another to the list of cases showing the intimate connection which exists between the presence of this parasite and such diseases as appear to imply some abnormality of the lymphatic system in tropical climates.

Dr. McLeod promises to publish full details of this very interesting case at no distant period.

Almost at the same time another person—the fifth suffering from this class of disease brought to my notice within a month—was kindly sent to me by Dr. Henry Cayley, Surgeon to the Chandney Hospital. He was an East Indian, born and brought up at Madras, and suffering from a sixth attack of Chyluria. The first came on suddenly in September 1871, after a residence of two years at Coconada; and each subsequent attack has lasted about two months—the disease appearing and disappearing at irregular periods. He complains of great debility and thirst, and of a dull pain on the under surface of the scrotum, but he is able to attend to his duties as a clerk.

Eight slides of blood were prepared; four being obtained from each hand by means of a needle. Within a comparatively short time two dozen Hæmatozoa were counted in the eight preparations in a state of great activity. They were also present in the urine.

It will be observed that these Filariæ have now been traced *directly* to the blood in ten, and detected in one or other of the various tissues and secretions of the body in at least thirty individuals; and always associated with Chyluria, Elephantiasis, or some such, closely allied, pathological condition.

THE PATHOLOGICAL SIGNIFICANCE

OF

NEMATODE HÆMATOZOA.*

BY

T. R. LEWIS, M.B.

SOME interest having been taken in a report which I had the honour of submitting to the Government, in 1872, on the existence of innumerable immature nematode Entozoa in the blood of persons labouring under certain diseases, I trust that the following additional contribution towards the extension of our knowledge in the same direction will not be unacceptable. A few of the clinical observations made since the issue of that report have been incorporated in the reprint of it which appeared in the *Indian Annals of Medical Science*;† others have been made subsequent to these and have not appeared in any journal, and the announcement that the blood of pariah dogs is, not infrequently, somewhat similarly affected will, I believe, as regards India, be quite new; as will also the description of the pathological conditions frequently co-existing with this state in these animals—a pathological condition which I have not yet been able to find recorded with regard to the dogs of India or of any other country.

It will, perhaps, be as well to recapitulate in a few words the leading facts referred to in the report in its original form, so that readers of this paper who may not have seen the former will be the better able to form an estimate of the bearing of the observations now recorded on the facts and inferences then adduced.

These were to the effect that the blood of persons suffering from the diseased condition known as Chyluria contained minute nematode worms (evidently the embryos of some hitherto undetected nematode, provisionally named, for the sake of convenient reference, *Filaria sanguinis hominis*), averaging $\frac{1}{75}$th of an inch in length and having a transverse diameter of about $\frac{1}{3500}$th of an inch; not differing materially from the young of many other nematodes, except by the fact of their being enclosed in delicate, translucent sheaths, within which they can be observed to elongate and contract themselves so as to be able, within the space of a moment, either to occupy the entire length of the enveloping tube, or only one-half of it or even less than that: That I had obtained

* Forming an Appendix to the Tenth Annual Report of the Sanitary Commissioner with the Government of India, 1874.

† No. XXXII, January 1874, pp. 504 to 549, and reproduced in present Memorial Volume, pp. 503—532.

these entozoa in the blood of four persons, in the urine of about fifteen, and in the profuse coagulable discharge from the lachrymal or Meibomian ducts of one; all the persons being affected with Chyluria except one, whose history was unknown and could not be ascertained: That one of the cases had been under observation for more than two years, during which period the young Filaria had undergone no appreciable change, at least in so far as could be inferred from the fact that those which I had detected in his urine in March 1870, differed in no way from those found in his blood as well as in the urine in October 1872.*

It was further stated in the report that one of the persons, a European woman, suffering from Chyluria, in whose blood I had frequently detected Hæmatozoa, had died at the Medical College Hospital, and that Dr. McConnell, the Professor of Pathology, had made a very careful *post-mortem* examination, without the slightest evidence of any parent to the parasites being obtained, although in the kidneys and supra-renal capsules, which Dr. McConnell had kindly forwarded to me, numerous examples of the young were found without difficulty. The following passage describes the state of these organs: "No morbid changes could be detected as having taken place in either the tubular or cortical tissue of the kidneys, but in every fragment, no matter from what part of the kidneys removed, numerous microscopic Filariæ were invariably obtained, if the tissue had been properly teased, precisely analogous to those which had been detected in the blood and in the urine during life. Teased fragments of the supra-renal capsules yielded similar specimens. On slitting open any portion of the renal artery, from its entrance into the kidney as far inwards as I was able to follow its ramifications, and gently scraping its inner surface, numerous Hæmatozoa could always be obtained. The renal vein, when similarly examined, also yielded specimens of the Filariæ, but they did not seem to be so numerous in it."

From these observations it was inferred that the disease commonly known as Chyluria, was generally, if not always, due, directly or indirectly, to the presence of this entozoon in the system, and that the condition of the urine could only be looked upon as one of the symptoms of the existence of this parasite, although it appeared to be the most characteristic symptom with which we were acquainted; and lastly, the opinion was expressed that some of the hitherto inexplicable phenomena by which certain tropical diseases are characterised might eventually be traced to the same or to an allied origin—such diseases being implied as would naturally suggest themselves to professional readers wherein some impediment to the flow of the nutritive fluids of the body appeared to have occurred, as is commonly believed to be the case in various elephantoid conditions; especially such of them as were characterised by the exudation of a more or less chyle-like fluid from different parts of the body, and which have

* It may here be stated that young Filariæ remained in the vascular system of this person without undergoing any appreciable morphological changes until April 1873. He was at this period admitted into the Presidency General Hospital, under Dr. Coull Mackenzie, suffering from diarrhœa, which, however, soon passed off. He then became subject to frequently recurring attacks of fever, and died rather unexpectedly in a state of high delirium. Unfortunately no *post-mortem* examination could be held.

commonly been attributed to various obstructing causes, such as the pressure of tumours, idiopathic diseases of nerves and vessels—doubtless in many instances quite correctly so. "Nevertheless," it was maintained, "cases occurring in warm countries, or in persons who had formerly resided in them, appear to indicate that the disease is, probably, not dependent on such mechanical or pathological causes as these."

Since these remarks were published, several cases of such a nature have come to my notice, and all have been, when diligently inquired into, confirmatory of them in the highest degree.

Before referring to these, however, it will be more convenient to study the pathological conditions associated with the existence of young nematode worms in the blood of the pariah dogs referred to in the opening paragraph, in order to ascertain whether some more satisfactory clue can be obtained by means of comparative data of this kind as to the pathological significance of the human Hæmatozoon here referred to, than can be derived from pure inference, or from the observations concerning nematode Hæmatozoa generally, hitherto put on record. A rapid retrospect of such of these observations as appear to be more or less closely associated with the subject may be of interest to such of my readers as have not made it a matter of particular study.

In a brief *résumé* of the more generally known Hæmatozoa among lower animals which was given in the former paper, reference was made to the discovery made by MM. Grube and Delafond, more than twenty years ago, of microscopic nematode worms in the blood of dogs in France.* They were about $\frac{1}{100}$th of an inch in length with a transverse diameter somewhat less than that of a red blood-corpuscle. Out of 480 dogs examined, from four to five per cent. were found to be thus affected; but on one occasion only were MM. Grube and Delafond able, by *post-mortem* examination, to detect parasites in the bodies of the animals, visible to the naked eye, which could be looked upon as parents to the microscopic worms in the blood. On the occasion referred to, however, they were able to satisfy themselves on this point by the discovery of six *white*, filiform worms (four males and two females) in the *right* ventricle of one of the animals. These were from five to seven inches in length and from $\frac{1}{25}$th to $\frac{1}{16}$th of an inch in width; the anatomical details could be clearly made out, as also the stages of the development of the ova in the ovaries and of the embryos in the oviducts, the embryos being considered identical with the microscopic worms in the blood.

In the same paper attention was also drawn to the observations recorded concerning the worms found, frequently and in considerable numbers, in the *right* cavities of the hearts of dogs in China and elsewhere. These are commonly looked upon as identical with the mature examples found by MM. Grube and Delafond, and we have now the high authority of Dr. Cobbold for considering those of China at least, as identical with the *Filaria immitis* of Leidy.†

On referring to a description of the American parasites by Professor Leidy, which, by the way, in the first record we have of them, were named by him *Filaria canis*

* *Comtes Rendus*, tome XXXIV, 1852, pp. 11—14. † *Lancet*, vol. I, 1873, p. 462.

cordis,* we find it stated (in addition to the various anatomical details common to the Filaridæ, among others that the caudal extremity of the male is provided with "a row of five tubercles and a narrow ala upon each side") that the length of the female is 10 inches, and the breadth $\frac{1}{2}$ a line; length of male 5 inches, and the breadth $\frac{1}{4}$ of a line. The Professor continues—"Mr. Joseph Jones lately presented to me two specimens of the heart of a dog, in the *right* ventricle of one of which there were five of the Filariæ just described. In the other specimen the right auricle and ventricle and the pulmonary artery in its ramification through the lungs are literally stuffed with Filariæ." A portion of the blood of this dog contains a great number of the young of the Filariæ. Both these animals are referred to as being very lean—one is described as being "so thin as to resemble a skeleton, and it was impossible to benefit his condition with the most liberal supply of food."†

Mr. Leidy does not give the minute anatomy of these Filariæ, nor does Schneider, whose description generally coincides with that of Leidy, and accurately so with reference to the caudal extremity of the male ‡); but the omission as to the microscopical characters of the worm has been so exhaustively supplied by Dr. Welch, Assistant-Professor of Pathology at Netley,§ and by Professor Cobbold,‖ that there can be no possible excuse for future workers in this field of research to confound totally distinct Entozoa.

It should be noted that the mature worms discovered in France, China and America, are described as being found in the cavities of the *right* side of the heart and vessels of the *venous* circulation.

Dr. Cobbold has also recently called the attention of English readers to a paper in Virchow's *Archiv* for 1865, by Professor Leiserung, on the existence of minute, though mature, parasites in the *venous* blood of certain parts of the circulation of dogs—males, females and embryos being found. The female worms (presumably larger than the male) did not exceed $\frac{1}{12}$th of an inch in length and the free embryos averaged $\frac{1}{108}$th. Dr. Cobbold considers the parasites to belong to the strongyloid group of worms, and has given other particulars concerning them in his lately published excellent manual "On the Internal Parasites of our Domesticated Animals,"—a work which, I regret, is not at present in my possession, as I am thus obliged to fall back upon the few hasty notes which were made whilst perusing the volume a few weeks ago for the particulars just given of Leiserung's observations.

The foregoing paragraphs contain the leading features of all the information which I have been able to glean with reference to the existence of Hæmatozoa in dogs: I could find no allusion whatever to any such condition being manifested by dogs in India.

* Proc., Acad., Nat. Science, Philadelphia, vol. V, 1850-51, pp. 17, 18.
† *Op. Cit.*, vol. VIII, 1856, p. 55.
‡ Monographie der Nematoden, 1866, p. 87.
§ Monthly Microscopical Journal, October 1873, pp. 157—170.
‖ Proc., Zoological Society, London, November 1873, pp. 738—741.

Whilst making a microscopic examination of some gland tissue from the mesentery of a pariah dog (last July), I observed that the sanguineous fluid squeezed out of the preparation on the slide contained numerous minute nematode worms in a state of great activity, and presenting at first sight a marked resemblance, both as to the character of their movements and their size, to the Hæmatozoon referred to above as existing in human blood. I had for a long time been desirous of obtaining living specimens of a canine Hæmatozoon so as to be able to institute a comparison between this kind and those found in man, although I had not entertained any very sanguine hope of being able by this means alone to pronounce definitely as to the identity or otherwise of the two parasites, for it has long been known that the embryos of many Filariæ of widely differing size and habitat present no appreciable difference either of size or form: instances being known of the young of even a totally distinct group of nematodes being nevertheless so like as to be miscroscopically undistinguishable the one from the other.

It was, however, very evident that should any anatomical or other marked discrepancy be observable in parasites subject to the same influences, there could be no difficulty in coming to a very positive opinion on the matter. With reference to the particular Hæmatozoa under consideration, the anatomical disparities are so unmistakable that I have not the slightest hesitation in pronouncing them to be totally distinct parasites. Dr. Douglas Cunningham, who has repeatedly and most carefully examined both kinds in the living state, is equally satisfied on this point.

For the sake of comparison, figures have been introduced of these human and canine Hæmatozoa (Plate XXXVIII, Figs. 1, 2), from which it will be perceived that they correspond very closely as to size: the average measurements of the latter may be stated as about $\frac{1}{90}$th of an inch from end to end, and about $\frac{1}{4500}$th at the widest part, the average dimensions being slightly smaller than those yielded by the human parasite. The relative proportion of the breadth to the length in the canine variety is about 1 to 50, the tail occupying about $\frac{1}{5}$th or $\frac{1}{6}$th of the total length—the relative proportions also differing somewhat from those of the young *Filaria sanguinis hominis*.* The measurements and proportions, however, vary to some extent according as the parasite is measured in the extended or the contracted condition.

I can detect no indication whatever of this canine hæmatozoon being enclosed within any enveloping tube, such as the structureless, hyaline, tubular sac, enclosing the human parasite, and within which the latter parasite can be observed to contract and elongate itself—no portion of it being structurally adherent to the enclosing sac.

* On one occasion I detected a specimen in the blood of a dog yielding much lower measurements, *viz.*, $\frac{1}{175}$ of an inch in length by $\frac{1}{6500}$ of an inch at the widest part, the breadth being to the length as 1 to 34. In this respect also the canine embryo parasite differs from the *Filaria sanguinis hominis*, as the proportion between the breadth and the length in the smaller specimens instead of diminishing, as in the canine variety, increases considerably—the smallest specimen which was measured of the human variety having been $\frac{1}{7500}$ of an inch at the widest part, and $\frac{1}{125}$ of an inch in length; the width being to the length as 1 to 56, whereas in the larger specimens it was found to be as 1 to 45.

Whether this tube is the old cuticular covering of the embryo, which parasites of this kind are known to cast off during the process of development, and which, under this altered condition, becomes more permanent (for it can hardly be supposed that the blood is the natural habitat of this parasite, seeing that no very evident developmental changes take place), or whether it be merely the dilated, attenuated covering with which the embryo was originally invested, I am unable to decide.* As the cyst invests the parasite very closely laterally, and is, to some extent at least, elastic, there is frequently some difficulty in distinguishing it from the body of the worm proper, especially when, as is usually the case, the fluid in which it is found contains molecular matter which obscures the minute structure of the parasite; or when death occurs, as is commonly the case, whilst the worm is fully extended, and it thus occupies the whole length of the tube. During life, however, when the movements are not too rapid, and the field is cleared of molecular matter, the saccule may, as far as my own experience goes,—and I have examined some thousands of specimens,—always be distinguished if the microscope be good and the illumination properly adjusted.

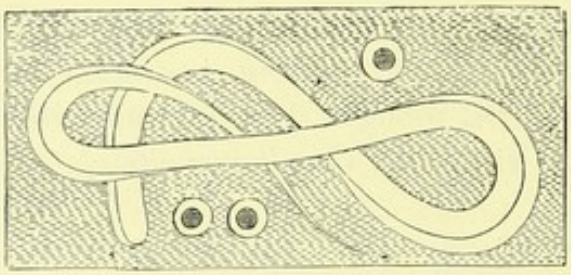


FIG. 34.—The Canine Hæmatozoon and three red blood-corpuscles fixed in serum by osmic acid. The clear space alongside the parasite is owing to the removal of the film of serum by contraction of the worm. × 600.

On one occasion it seemed as though I had succeeded in detecting such a cyst in the canine Hæmatozoon—a lifeless specimen immersed in fluid, but subsequently it was found that the appearance observed was due to the specimen having been torn across a short distance from the caudal end; the granular substance of the worm had escaped at the part, thus leaving a hyaline tube (containing, however, a few oil molecules) formed by the investing membrane proper of the worm: the detached fragment was subsequently found on the same slide.

When specimens of the blood of the dog infested with these parasites are spread out in very thin layers upon glass slides and subjected to the fumes of osmic acid, in the manner recommended on a former occasion in connection with the *Filaria sanguinis hominis*, a deceptive appearance is frequently produced by the contortions which the worms may undergo during the process of "setting" of the serum. A

* Since this was written, I have observed that Schneider has suggested a somewhat similar explanation with reference to the capsule which appears to envelop the young of *Ichthyonema globiceps:* "Embryonen von einer Hülle umgeben, ob dieselbe durch Häutung oder durch Erweiterung der Eihülle entsteht, ist ungewiss"—Monographie der Nematoden, s 175.

double outline results highly suggestive of an enveloping cyst. The osmic acid appears to act on the serum before causing the death of the Filaria, so that the latter contracting after the serum has become partially solidified produces a clear space, which may be evident at either end or alongside the worm, as may be observed in the accompanying woodcut.

It will, however, be sufficiently clear that this appearance is produced by the *ante-mortem* contractions of the parasite, from the simple fact that the spaces are nearly always along the convexities of the outline of the worm. Had the spaces been due to the folds of a cyst, they would have been found along the concavities.

Notwithstanding these minute anatomical discrepancies, which are of importance in considering the natural history of the two parasites, their resemblance is sufficiently striking, that I would strongly advise those who are interested in the human Hæmatozoon, and have not had the opportunity of examining it for themselves, but are anxious to obtain a more definite conception of the *Filaria sanguinis hominis* than can be obtained from written descriptions and drawings, to make arrangements with some of the low-caste persons employed in destroying sickly, pariah dogs, to collect a few ounces of the blood of these animals.

The fluid should be examined at first by means of a low power, such as a $\frac{2}{3}$rd of an inch objective—the layer of fluid between the slide and the covering glass being as thin as possible. Should any worm-like body manifest activity on the slide, the $\frac{2}{3}$rd objective should be replaced by a good $\frac{1}{4}$th or still better a $\frac{1}{8}$th of an inch immersion object glass. Should, however, this procedure not prove successful after having tried several dogs, it will be found advisable to get the aorta itself and gently scrape its lining membrane with the edge of a covering glass. Should the dog be affected at all, the probability is that the parasite will be found here. It must not be expected that the blood will present any peculiarity to the naked eye, even though every ounce may contain thousands of embyro-worms.

With regard to the movements of the canine variety, it may be stated that they are strikingly like those of the *Filaria sanguinis hominis*, and not materially different from the movements of Filaria-embryos generally. I have, however, frequently observed the canine worms attached, at the oral extremity, to the under-surface of the covering glass, or to the slide, and swinging in all directions from this fixed point—the oral extremity being blunted whilst in this condition. I have watched them thus attached for more than an hour, but have not observed a similar feature in the movements of the human variety.

The internal structure of both is pretty much alike; in neither is there any visible differentiation of the reproductive organs, and only in a very minor degree of the alimentary tract; if anything, the canine parasite is perhaps the more advanced.

With reference to the degree of prevalence of this condition among dogs, it may be stated that of the animals which I have examined in Calcutta with this special object in view, more than a third were found to be affected. I have kept

notes of twenty-seven such examinations, and find it recorded that the blood of ten of these dogs was found to be invaded to a greater or less extent by these embryo-worms.

Before attempting to arrive at any conclusion as to the probable or possible source of these embryos, it will be advisable to describe briefly the pathological conditions which usually accompany their presence. These, as far as may be inferred from very careful dissections of the twenty-seven dogs above referred to, may be described as follows:—

1. The most striking feature is the existence of fibrous-looking tumours, varying from the size of a pea to that of a filbert or walnut, along the walls of the thoracic aorta and œsophagus, both tubes being affected, or only one. (Plate XXXVIII, Fig. 8.)
2. Minute nodules in the substance of the walls of the thoracic aorta, from the size of duck shot to that of split peas. They can be felt as tubercles, and usually project somewhat on the outer surface of the vessel; a depression or slight extravasation of blood, corresponding to the nodule, being visible on the inner surface of the aorta (Plate XXXIX, Figs. 9, 10), and frequently a slight abrasion of the lining membrane.
3. A pitted or sacculated appearance of various portions of the interior of the thoracic aorta with thinning of its walls at some parts; the lining membrane roughened at the spots affected; the roughening, however, is not of an atheromatous character, but due to the membrane being thrown into delicate rugæ, as if from contraction of the middle and outer coat.
4. Enlargement and softening of some glandular body adjoining the vessels at the base of the heart.

Within the above four headings is comprehended everything abnormal that I have been able to detect, which seemed to imply any connection with the state of the blood under consideration.

(1)—As regards the first point referred to, the tumours manifest a somewhat firm, fibrous texture, and when cut into are found to contain one to six or more mature nematode worms, of a pinkish, sanguinolent tint, and varying in size from one inch to three and a half inches in length. These on closer examination prove to be the male and female of the same parasite: the male worm being from one to two inches long, and $\frac{1}{50}$th to $\frac{1}{40}$th of an inch in diameter at the widest part; and the female from two to three and a half inches long with a transverse measurement of from $\frac{1}{30}$th to $\frac{1}{25}$th of an inch. (Plate XXXVIII, Figs. 3, 4.)

These parasites correspond more closely to the *Filaria sanguinolenta* (Rudolphi), especially to the description of this species given by Schneider, than to any other nematode with which I am acquainted, although in some respects they differ from the descriptions given of any.

It is, however, with regard to the parts of the body in which these parasites are

found that the most marked discrepancy exists, for all writers, as far as I am aware, with the exception of Czernay,* appear to speak of them as confined to the walls of the stomach† of the dog or wolf. This writer, however, has drawn attention to the

* Bulletin de la Soc. Imp. des Naturalistes de Moscow, Tome xxxviii.

† With regard to the statement made by writers generally, that the *Filaria sanguinolenta* is principally found in the walls of the stomach, it may be remarked that on no occasion have I observed any such occurrence in India. The only parasite with which I am acquainted, located in this situation, is one which I am unable to refer to any described species. It is lodged in a tumour, generally of the size of a small horse chestnut, continuous with the walls of the stomach. The tumour presents a hard fibrous texture, and communicates with the interior of the stomach by a small orifice into which a portion of the lining membrane of this viscus appears to be reflected. When cut into, two, or more, worms will be seen coiled in a hollow in the centre of the tumour.

These worms vary in length from $\frac{3}{4}$ths of an inch to an inch, with an average diameter of about $\frac{1}{20}$th of an inch. When placed under a microscope, the anterior half of the body is seen to be covered with sharp spines; and rows of tænia-like hooklets (Fig. 35, 5) encircle the dome-shaped "head." The "head," or rather proboscis, is frequently so completely retracted as to be altogether invisible (Fig. 35, 2). When protruded, two prominent "lips" of complex conformation project beyond the globular "head," disposed laterally, each being surmounted by a papilla permeated by a duct—not a nerve, as particles may occasionally be observed to escape from these two papillæ (Fig. 35, 3).

The upper portion of the body is covered with chitinous spines, arranged like plates of armour, each

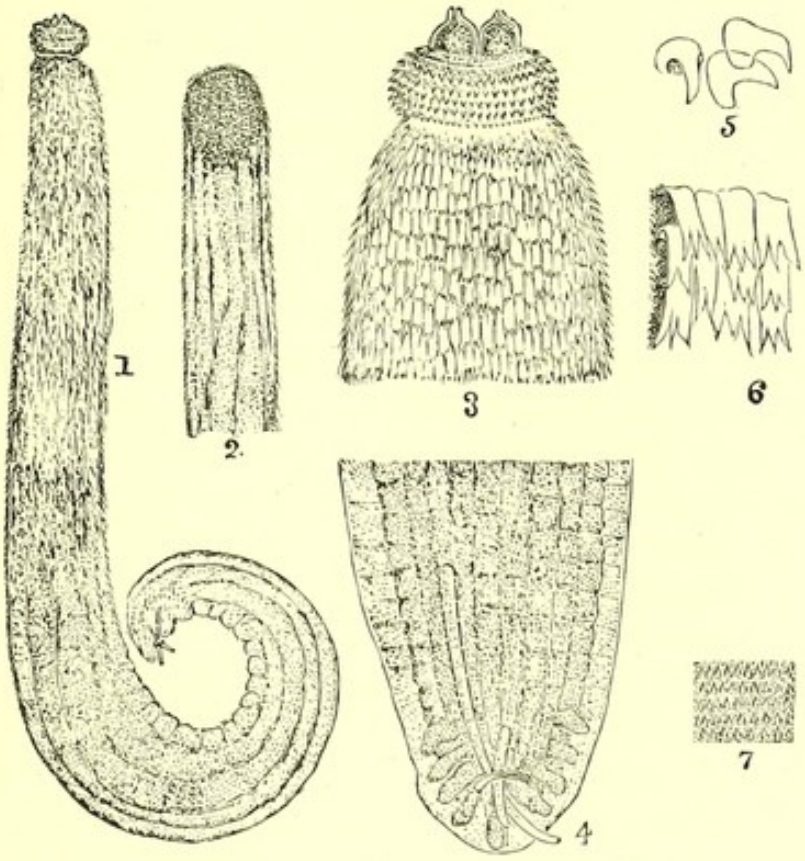


Fig. 35. ECHINORHYNCHUS FROM THE WALLS OF THE STOMACH OF A PARIAH DOG.

No. 1.	The parasite entire: proboscis exserted (Male)	×	6
„ 2.	Anterior portion of parasite; proboscis retracted	×	6
„ 3.	Ditto ditto ditto exserted	×	25
„ 4.	Posterior portion of parasite	×	25
„ 5.	Hooks surrounding proboscis	×	260
„ 6.	Prickly plates covering the anterior portion of the body	×	260
„ 7.	Small hooks arranged in rows on posterior portion of the body ...	×	260

fact that they may also be found in the walls of the œsophagus. Notwithstanding the somewhat extended reference to the works of systematic writers on these and allied subjects, which, through the courtesy of Mr. Wood-Mason, Curator of the Indian Museum, I have been able to make, I can find no mention of their lodging themselves in the walls of the blood vessels.

(2)—As far as the aorta is concerned, the condition referred to under the second heading is the one of most frequent occurrence; and as in this condition the parasite may be obtained in various stages of advancement, it will be better to describe the smaller tumours and their contents before referring more minutely to the mature *Filaria*, especially as this will give an opportunity of studying the growth of the parasite from a very early period till it reaches maturity. Specimens in almost every stage of development may sometimes be found lodged in the walls of a single aorta.

Although the tumours enveloping the young are much smaller than those in which the mature worms are usually lodged, the lesions, as far as the tissues of the walls of the artery are concerned, appear to be of a more serious nature, for frequently the walls of the vessel are very fragile at various places and there is a considerable roughening of its inner wall.

Towards the earlier stages of the attack of this parasite, a cursory examination of either the inner or the outer surface of the aorta may not convey to the observer the impression that there is anything unusual present, but on closer inspection slight indications of roughening or of dryness of the inner surface will be evident, as if indicative of commencing atheromatous changes. There may be either a small depression at the part or a slight elevation, and when the artery is drawn between the finger and thumb, a little tubercle, varying in size from that of a millet-seed to that of a pea, may be more or less clearly evident. (Plate XXXIX, Fig. 10.) Frequently also, on careful examination, a thin serpentine line may be detected lying immediately beneath the inner coat of the artery. (Plate XXXIX, Fig. 9.)

When one of the smaller tubercles is cut into and the tissues carefully dissected under a low magnifying power, a curled, hair-like object will generally be observed (Plate XXXIX, Figs. 9, 10); this, when examined under a higher power, will be found to

little plate terminating in two or three sharp spikes (Fig. 35, 6), the points being directed backwards. The tail of the male is slightly pointed, has a well-marked transverse slit on its ventral aspect, through which two spicules of unequal length occasionally emerge, and on either side four granular processes (papillæ?) are seen to diverge from the middle line, with one papilla-like ray extending to the tip of the tail (Fig. 35, 4). There is no bursa, properly so called, nor are there distinct alæ, but in a state of contraction the orifice, through which the spicules escape, is pulled up, so as to give rise to a funnel-shaped cavity. There are numerous transverse rows of minute hooklets with the points directed forwards, extending from the caudal orifice upwards, about as far as the upper end of the longer spicule when retracted; their number and size diminishing as they extend upwards (Fig. 35, 7).

I have not been able to make out the existence of either oral or anal apertures, nor been able to isolate any structure analogous to an alimentary canal, and conclude, therefore, that the parasite is an *Echinorhynchus*—possibly a hitherto undescribed species. All the specimens which I have examined have been males.

be an immature worm, but manifesting considerable evidence of organisation and in a state of great activity. They may be so small as not to exceed $\frac{1}{10}$th of an inch in length or more than $\frac{1}{150}$th transversely at the widest part. Some yield even smaller measurements than this.

At this stage of development no reproductive organs can be discerned. The oral end terminates in two pointed papillæ, dorsal and ventral, which can be brought closely together, so as to form a sort of "borer," by which means, possibly, the parasites bore their way through the tissues. (Plate XXXIX, Figs. 11 to 13.) The alimentary canal is well differentiated, the œsophagus occupying above $\frac{1}{3}$rd of the entire length of the worm: a well-marked sphincter-like constriction exists a short distance below the mouth, probably indicating the junction of the pharynx with the œsophagus. The intestinal canal terminates on the convex surface, a short distance from the end of the tail; the latter is somewhat blunt, and is tipped with a trefoil-like object (glandular?), communicating with a tube and apparently containing a transparent fluid. (Plate XXXIX, Fig. 13.)

During this period of its growth the worm undergoes a moulting process—casting off its skin entirely. (Plate XXXIX, Fig. 12.) When the cuticle has become somewhat separated from the body of the worm shortly before the "moulting" actually occurs, the continuation of the old cuticle with the lining of the oral and anal orifices is very evident, as also the fact that it forms a coating to the tri-lobed gland-like object at the caudal extremity.

This process of moulting appears to be repeated several times, and each time some slight modification occurs in the appearance of the worm, especially at both ends; it also increases in size. The prominent papillæ with which the mouth is furnished gradually disappear, and, by the time that the worm has acquired a length of about $\frac{3}{4}$ths of an inch, reproductive organs can be distinctly made out and the sex identified. No ova, however, can be detected in the genital tube of the female at this stage (Plate XXXIX, Fig. 14), and the spicula in the male are not developed until after the spermatic tube and the sheath of the retractor muscles of the larger spicule. The œsophagus is proportionally much shorter, and the tri-lobed object at the caudal extremity almost completely disappears.

The worm gradually acquires a more decidedly pinkish hue, and instead of occupying a little tumour alone, as it did when very small, it appears to make its way into some adjoining tumour. Other worms also migrate to this, so that one tumour may be common to several parasites. It should, however, be noted that they do not all occupy a single cavity, but each tumour is tunnelled in various directions, so there is frequently some difficulty in pulling out the parasites without tearing or otherwise injuring them.

Sometimes they may be seen to have crept outside the tumour, lying between it and the serous covering investing the artery, or a parasite may be seen emerging through a minute orifice communicating between the tumour and the interior of the

aorta and swinging itself across the lumen of the artery (Plate XXXVIII, Fig. 7). I have observed the channel of the aorta almost entirely blocked up after death by a clot which had formed around a worm in this position.

When the parasites have acquired a length of about $\frac{3}{4}$ths of an inch to an inch, and a transverse diameter of about $\frac{1}{40}$th, they will be found to have acquired nearly all, if not all, the microscopical characters distinctive of the *Filaria sanguinolenta;* and, as already mentioned, every stage in the development may be represented by examples of the parasite in the tissues of a single aorta—in the thoracic portion of it: I have never observed the abdominal aorta to be affected in this manner, nor have I observed the parasite in this condition in any tissue beyond the limit of the thoracic cavity.

(3)—With regard to the third heading into which the pathological features of this phase of parasitism has been divided, namely, the sacculated external and scarred internal appearance of the aorta, it may be observed that these changes appear to have been produced by the development of the Filaria as above described, by their subsequent migration to adjoining tumours and various tissues; and probably, also, by the death and subsequent softening and absorption of some of the parasites —an assumption supported by the fact that, frequently, on pricking an affected spot of this kind, on the walls of the aorta nothing is found except an accumulation of soft pultaceous substance filled with fatty molecules and plates of cholesterin.

(4)—Sometimes the three foregoing classes of morbid appearances may be found to occur in a single animal; indeed, the only occasion on which I observed the condition described under the fourth heading, now to be referred to, was also associated to some extent with the other three. The blood of a dog was found to be affected to a slight degree with Hæmatozoa, and the aorta was scarred and nodulated; but no mature parasites could be detected anywhere, except in a tumour in the walls of the œsophagus. On careful examination of the thoracic viscera, however, a gland, or what seemed to be one, was observed to have become enlarged and softened near the origin of the left carotid artery. (Plate XXXVIII, Fig. 8.) This tissue, on being cut into, was found to have degenerated into a pultaceous mass composed of oil molecules and plates of cholesterin; but coiled in the midst of this softened material were five mature specimens of the *Filaria sanguinolenta*—male and female.

This observation shows that the mature parasites, at all events, may be found in other tissues than those of the thoracic aorta and œsophagus.

It is not deemed necessary to enter into any very minute description of the anatomical characters of the mature *Filaria sanguinolenta* as found in dogs in India, as these do not differ very materially from those of various other Filariæ which have been described by various writers from time to time.

The figures in Plate XL will, I trust, be sufficient to give a tolerably clear idea of the general appearance and internal anatomy of the mature Entozoon when examined under the microscope; but it should be remarked that, in some instances, a higher

power has been used to make out the structures than the extent of amplification stated opposite each figure would imply. To have drawn the figures to scale, as observed under higher powers, would have added greatly to the difficulties of reproducing them without adding materially to their value. Figure 16, Plate XL, represents the anterior portion of the mature parasite; the mouth with its six, indistinctly marked, "lips;" the chitinous pharynx, and the upper portion of its muscular œsophagus: whilst the adjoining Fig. (17) gives the appearance of the mouth and entrance to the pharynx as seen from the front. Figure 18 represents the ventral aspect of the tail of the male with its two dissimilar spicules and four pre-anal papillæ—characters which, when taken in conjunction with the arrangement of the muscular tissues of the body, form the distinctive features of the genus *Filaria* (Schneider). There are also two post-anal papillæ, placed transversely to the body of the worm; so that in all there are twelve papillæ, terminating on the inner surface of the alæ which form the boat-shaped cavity on the ventral aspect of the coiled tail of the male.

The mode of formation of this cavity will be more readily comprehended by a reference to Fig. 19, which represents a dissection of the tail of the male as seen from the side (magnified 30 diameters). It will be observed that the cuticular and muscular sheaths of the worm have been slit up, and the two retractor muscles (*e e*) continuous with the sheath (*f*) of the larger spiculum, are seen to arise from either side of the left lateral band. (The well-marked curvature of the tail in the male, so common among the *Filaridæ*, is, in this case certainly, due in a great measure to the strength and elasticity of the larger spiculum; when this is extracted the curvature loses its firmness.) The alimentary tube (*a*) is seen to run parallel with the spermatic tube (*b c*), a sphincterlike constriction occurring on the course of the latter, separating the "*vas deferens*" (*b*) from the "testis" (*c*). The "testis" consists of a tube extending upwards in a serpentine manner until the junction of the upper with the middle third of the body and terminating cæcally as shown at (*d*). Figure 20 represents the molecular and cellular contents of this tube.

The head of the female worm (Fig. 21 *a*) does not differ from the head of the male, except that it is somewhat larger. The specimen delineated had been immersed in spirit, which had separated the chitinous cuticle from the other tissues; so that the continuation of the former with the pharynx has been made very evident, the pharyngeal membrane being merely a reflection inwards of the skin; a similar reflection takes place at the other end of the alimentary canal. The course and texture of the œsophagus and intestinal canal are the same as in the male, and do not differ from such structures in the *Filaridæ* generally.

The vagina (Fig. 21 *b*) terminates about $\frac{1}{6}$th of an inch below the oral extremity generally a little above the junction of the œsophagus with the intestine, as represented in the plate. It is a well-developed muscular tube, composed of longitudinal and transverse fibres, and the channel is occupied by a row of ova lying two or three abreast. It is about $\frac{1}{4}$th of an inch in length, is curved upon itself about the middle and

divides into the two uterine tubes delineated in the figure (21 *b*). These tubes are also filled with ova, each ovum containing a more or less clearly differentiated embryo, especially towards the vaginal end; but in no part of the genital tract are free embryos to be found. On tracing the course of the uterine tubes by means of a low power until within about a quarter or half an inch of the caudal extremity (Fig. 21 *c*), they are found to terminate in still smaller tubules (the ovarian); and these, after forming numerous coils around and alongside the intestinal tube, terminate abruptly in a cæcal manner, retaining pretty much the same diameter throughout their entire course.

The caudal extremity (Fig. 21 *c*) of the female is not so complicated as that of the male; it is very slightly pointed, and at its extremity something suggestive of the remnant of a gland, or of the site of *exit* of the water-vascular system, may frequently be discerned: in the male also a similar appearance may often be detected.

The ova in the earlier stages are oval, but as the development of the contained embryo advances, the firm, though thin, "shell" becomes more elongated and the ends of the ovum more blunt (Plate XXXVIII, Fig. 5). The ova are about $\frac{1}{750}$th of an inch in length and about $\frac{1}{1600}$th in width. When a ripe ovum is crushed beneath the covering glass a well-developed embryo escapes, which, however, does not manifest any activity (Fig. 6).

The embryos when thus deprived of their covering vary somewhat in size, the average dimensions of the particular specimens measured were found to be about $\frac{1}{200}$th of an inch from end to end and about $\frac{1}{6000}$th at the widest part—just $\frac{1}{30}$th as broad as long. With reference to these embryos it may be further remarked that the thickish, yellowish fluid in which the mature worms are imbedded may be squeezed through the orifice in the tumour (usually found without difficulty) communicating either with the aorta or the œsophagus, according to its anatomical relations. In this way innumerable ova may be made to pass into either channel, as the fluid is well charged with eggs in all stages of development.

I have not, however, observed any free embryos in this fluid, nor could I find any along the whole course of the intestinal canal in the dogs examined, where the parasites were lodged in tumours in the œsophageal walls, although plenty of ova, apparently unaltered, could be detected throughout the entire gut.* On one occasion only have I observed ova on a slide of blood containing Hæmatozoa: this preparation was obtained by scraping the inner surface of the aorta with the edge of a covering glass.

It would, therefore, appear that the ova require some considerable time before the escape of the embryo takes place, certainly a longer period than is sufficient for them to be conveyed the entire length of the intestinal canal.

I have made numerous attempts at bringing the embryos to maturity: by means of moist earth; by feeding cockroaches with bread soaked in fluid containing ova; by introducing ova into the stomach and peritoneal cavity of frogs, etc., but have not yet succeeded—the ova and their contained embryos being, from a week to a fortnight

* *Dochmius trigonocephalus* is the ordinary nematode Entozoon found in the intestines of dogs in India.

afterwards, detected in the bodies of the animals without having undergone any apparent change.

Where the true habitat of these embryos may be is as yet unknown. Whether, after a lengthened sojourn in moist earth, or in water, or in the intestinal canal of some creature other than the dog, the embryo escapes and undergoes developmental changes, must be left for future inquiry, as must also the direct proof that the microscopic worms in the blood of the pariah dog are the brood of the *Filariæ sanguinolentæ* which may be lodged in the wall of the aorta or œsophagus, or in some other tissue, glandular or connective, about the base of the heart or elsewhere. All that I can say is that all my attempts at finding any other mature nematode in the vascular system of dogs affected with Hæmatozoa have proved fruitless, and I have made careful examinations—macroscopic and microscopic—of every tissue and organ of the bodies of several animals, and followed the ramifications of the various arteries and veins in the trunk and in the extremities. On one occasion, no trace of any mature parasite in a Hæmatozoa-affected dog could be found, but it is quite possible that the parent may have escaped detection by being lodged in some out-of-the-way tissue in the body, and one worm might contribute many thousands of ova; or the worm, after depositing its ova, may have taken its departure, or have died, and become disintegrated. The scarred and sacculated condition of the aorta, already described, which is sometimes observed unassociated with any parasite at the time of the examination, shows that the worm that produced the lesion may altogether disappear.

Moreover, we require to know far more than is at present known concerning the development and parentage of these canine microscopic blood-worms, before anything definite can be stated with reference to their relationship to similar organisms found in the blood of dogs in France, China, Japan, and America.

So far as I am aware, Dr. Spencer Cobbold is the only author who has suggested that the young of the *Filariæ sanguinolentæ* may possibly find their way into the blood* —a suggestion which is the more noteworthy, seeing that, to the best of my knowledge, no observations had been recorded showing that this nematode ever penetrated the arteries.

Although I have not been able to keep individual dogs affected with this Hæmatozoon during any lengthened period, still there can hardly be any doubt but that, as has already been shown with reference to the human Hæmatozoon and been previously remarked concerning Hæmatozoa in animals generally,† these microscopic worms may exist for a considerable time in the blood (unaltered after having attained a certain, very imperfect stage of development), showing that they were not in the place or fluid fitted for their growth. Their presence in the blood, it may therefore be presumed, is accidental, or if not exactly accidental, the young brood requires at least to be transferred to some other habitat before undergoing even the most elementary morphological changes.

* Entozoa: an Introduction to the Study of Helminthology, London, 1864 p. 95. Supplement to ditto, p. 63.

† In dogs in France and China; in the frog; and in the crow.—Leuckart: *Op. cit.*, p. 102.

When, however, the ova or liberated embryos of the *Filaria sanguinolenta* find their way into a "host" or other medium suitable for their development during the larval stage—a stage in their development carried on, possibly, to the extent of providing the embryo with some kind of oral armature and a differentiated intestinal tube. Having acquired this stage of growth, the further progress of the parasite is probably dependent on its being swallowed by some such animal as the dog, to the mucous lining of whose œsophagus it attaches itself, then penetrating the muscular tissue of this tube and remaining there or working its way still further till it reaches the tissues of the thoracic aorta, or some other place suitable to its growth and development; the various stages of which, when the aorta has been selected, have been described on a previous page.

With reference to the morbid phenomena indicating the presence of these parasites in the vascular system of dogs during life, I have no definite knowledge. Some of the affected animals have been of the most miserable kind, others have appeared to be in the enjoyment of perfect health—facts which appear to me to favour the inference that when actual mischief does take place, the cause may be due to the lesions induced by the migrations of the growing and more or less mature parasite, rather than by the microscopic brood in the blood. It would not surprise me, should it eventually be demonstrated, that the haggard, loathsome appearance presented by the great number of the pariah dogs of every Indian town is, in many instances, primarily due to the injuries inflicted on the vascular and other tissues of the animals by these parasites—a diseased state which cannot be attributed to age or to want of food, for the associates of these animals, under the same conditions, are perfectly healthy.

In applying the lesson in pathology which these observations on animals appear to afford towards the elucidation of the diseased condition associated with nematode Hæmatozoa in man, it should be specially borne in mind that the parents of these blood-worms may be very much smaller than the mature Entozoa described above, consequently their detection at a *post-mortem* examination may be even much more difficult than is the case with the canine worms.

That this is probably the fact, the experience of an accomplished pathologist, Dr. McConnell, testifies, for, as already mentioned, he could detect no mature parasite in the body of a person whose blood, during life, was known to be contaminated with young *Filariæ*.

Since this paper was in type, I have, through the kindness of Dr. McConnell, had the opportunity of examining all the organs of the body of another person whose blood contained innumerable examples of these embryo-worms. The subject was a Native, aged sixteen, who had been brought to the Medical College Hospital in a moribund state. No previous history could be obtained, except that he had suffered from "fever," and he did not appear to possess any friends in Calcutta. The youth died within a few hours after admission, and Dr. McConnell made a *post-mortem* examination of the body on the following morning. No evidence of special disease could be found, but on making a microscopic examination of a clot of blood from the heart he was surprised to find

numerous specimens of the *Filaria sanguinis hominis*. He thereupon most kindly came to me, bringing some specimens with him, and invited me to make a minute examination of the body which had been specially set aside for the purpose.

On the following morning, some thirty-six hours after death, I made a careful examination of all the organs *in situ*, but failed to detect any mature parasite. The surface of the entire body was examined to make sure of the absence of such parasites as the Guinea-worm, as far as external marks would be a guide, but nothing was found

All the organs were preserved in spirit, as were also specimens of the various tissues of the body. I have since examined the heart with its vessels; the lungs; the liver; the spleen; the kidneys, and their excretory ducts; the bladder; the intestines; the brain, etc.; but have not, as yet, been able to detect any mature parasite—the embryo-Filariæ, however, were present everywhere in abundance. I regret that the final result of the examination cannot be recorded at present as the press cannot be delayed; but the fact that I have already spent two whole days in making the examination will be sufficient to show that it was more than a cursory one.

What are the salient morbid phenomena associated with the presence of nematode Hæmatozoa in man? As far as my experience has hitherto extended, they may be described as diseased conditions referable to the escape of the nutritive fluids of the body out of their proper channels into some organ or into the cellular tissue, or of obstruction to their fluid—the fluid extravasated being chylous, sanguineous, or a combination of the two.

Speaking generally, these morbid conditions may be described as manifesting themselves in two principal forms:—

1. As an exudation or extravasation into some excretory tract—especially the urinary:
2. As an exudation or extravasation into the subcutaneous tissues.

1. With reference to the escape of nutritive fluid into the urinary tract, it may be stated that, in addition to the fifteen cases of the diseased state commonly known as "Chyluria," described at length in the previous report on this subject, about fifteen more cases of the affection have come under my notice, so that ample opportunities have been afforded for putting the observations then recorded to the test. In these, as in the former cases, *Filariæ* were invariably detected, either in the blood, the urine, or in both.* The malady is not so very rare as is commonly supposed; indeed, on one occasion, as many as five fresh cases came under my notice within a single month. Some of these are of special interest, as illustrating peculiarities in the disease which were not evident in the cases previously recorded.

For one of the first cases which came under my notice since the publication of the first series of these observations I am indebted to Dr. Charles Macnamara. The patient was a house-keeper, age 52, the mother of six children, of whom two only are living.

* One of the persons affected in this manner had been a Leper for several years previous to the advent of Chyluria.

She informed me that four years previous to her visit to me in 1873, her urine had suddenly become of a milky aspect, but that in the course of a month it regained its normal appearance. Eighteen months subsequent to this the disease returned without any premonitory symptoms being observed. It disappeared as before, but returned as bad as ever. I pricked one of her fingers with a needle and distributed a drop of the blood thus obtained over six slides, in two of which several active Hæmatozoa were detected.

To Dr. McConnell I am again indebted for opportunities of observing several cases of Chyluria. One was a native shopkeeper, who, two years previous to his visit to me, had an attack of the disease, lasting for about six months. The morbid symptoms ceased suddenly, and did not return for four months, but when they did so he was affected for some three months or more. He was unmolested for the next seven months, at the end of which period the disease returned. It will be noted that during two years this person experienced three attacks of Chyluria, suffering from the disease for more than nine months out of the twenty-four.

A somewhat similar case, but rather more aggravated, was kindly sent to me by Dr. Henry Cayley. The patient was a young man, an East Indian, born and brought up at Madras, and suffering, when I saw him, from a sixth attack of Chylous urine. The first came on in September 1871, after a residence of two years at Coconada. All the attacks had lasted about two months each, so that from the first onset of the disease until now he has suffered for about twelve out of thirty months.

Hæmatozoa were present in the blood of both these cases; as many as two dozen were counted in eight preparations from the finger of the case last cited. The urine also contained the parasite.

I do not remember to have met with a patient suffering from an undoubted first attack of the disease until August of the present year—a case which is also of interest owing to the fact that the patient had never slept out of Calcutta, and had not travelled more than about 20 miles beyond it. The man, who had been referred to me by Dr. McConnell, was an East Indian, age 22, a printer. A month previous to the interview he had observed his urine to present a slightly milky aspect, on the second day the milkiness increased, and on the third a slight trace of blood was evident. The only premonitory symptoms had been "a dull, aching pain" over the lumbar vertebræ, which, however, was not so severe as to keep him from work. The pain had lasted for about three days before the urine became affected, and it seems to have passed off when the milkiness appeared. There was no previous history of the disease in the family, but his mother had suffered from hæmaturia two years ago.

The blood was examined and found to contain numerous examples of the *Filariæ*. I did not examine the urine, but Dr. McConnell informs me that he did so and found that *Filariæ* were present in it.

The four foregoing cases may be looked upon as fair examples of the disease

uncomplicated by any other known morbid condition, and may serve as types of the class in which the urinary tract appears to be the only portion of the economy whose functions are disturbed.

2. There is, however, another class of cases characterised by the exudation of nutritive fluid into the sub-cutaneous tissues, the fluid either accumulating and forming pouches under the skin and subsequently becoming exuded through orifices more or less minute, or retained until artificially evacuated to allay the pain caused by the tension produced on the surrounding tissues—which are generally in a state of hypertrophy. This affection has long been looked upon as intimately related to Chyluria, and, as already remarked, I considered it probable that the *Filaria sanguinis hominis* would before long be found associated with it as well as with Chylous urine. This inference I have since shown to be perfectly correct, so that now not only the pathology of these maladies, but the etiology also, is linked together by this parasite being found in the circulation of persons labouring from both classes of diseases. Dr. [now Sir Joseph] Fayrer, who probably has seen more cases of an elephantoid nature than any one living, has suggested the possibility of such an occurrence in his recently published work;* and Dr. W. J. Palmer, in an essay on some of the common forms of our local skin diseases, has expressed a somewhat similar view.†

The two classes may, however, be present in the same person, the urinary tract being previously affected in some cases and the sub-cutaneous tissues subsequently; whereas, in other cases, the Chylous urine symptoms may not be manifested for years after the advent of the elephantoid.

The first occasion on which I was able to satisfy myself on this point was towards the end of 1873, when through the kindness of Dr. Ewart I was able to examine some whey-like urine, highly albuminous, and exhibiting a tendency to coagulate. The patient, a Jew, was suffering from acute pain produced by an inflamed condition of a moderately large scrotal tumour. This tumour had been coming on for many years, and increased and diminished in bulk at irregular intervals. It was studded with tubercular prominences, soft and yielding to the touch, and when a trocar was introduced several ounces of a sanguineous fluid were withdrawn. This was, however, not found to yield sufficient relief, so that a more formidable operation had subsequently to be resorted to. The urine also contained occasionally a little coagulated blood in addition to the Chylous fluid, and *Filariæ* were detected in it on the two occasions on which specimens were examined microscopically by me.‡ The Chyluria had only been observed about a fortnight previously,

* Clinical and Pathological Observations in India: London, 1873.

† Indian Medical Gazette, Vol. VIII, 1873.

‡ Considerable difficulty was experienced in detecting the *Filaria* in this case. It required fully *five hours* of steady application to the microscope before a single specimen could be found, although they were subsequently found without much difficulty. In the reprint of the former paper on this subject in the "Indian Annals," the following remarks with reference to this matter were introduced as a foot-note:—

"I cannot avoid availing myself of the opportunity which this case also affords of reiterating the

The next case, for which I am indebted to Dr. Coull Mackenzie, was that of an East Indian 35 years of age. Unlike the preceding, the scrotal affection was of short standing, nine months only, and Chyluria symptoms had not yet set in. When the disease commenced it was looked upon as a hydrocele, and the tumour was repeatedly tapped, and a milky, pus-like fluid withdrawn. The swelling, however, continued to increase, became very painful, and eventually attained the size of a man's head. The patient was admitted into the Presidency General Hospital for "thickening and enlargement of the scrotum." The tumour was twice tapped in hospital, and the fluid removed sent to me for examination. It presented a somewhat purulent appearance, but the odour was not offensive. Under the microscope it was seen to consist of broken-down granular matter, and every slide of it contained some half-a-dozen specimens of *Filaria*.

With reference to the above it may be remarked that one of the patients suffering from Chyluria which I described in the previous paper,* and whose blood was shown to be affected with Hæmatozoa to an enormous extent, is now manifesting symptoms very like these, the scrotal affection having commenced some two years subsequent to those of Chyluria. Filariæ may still be detected in his system.

The third example of this class of the affection which I had specially observed was that of a middle-aged native, a patient of Dr. McConnell's at the Medical College Hospital. He was suffering from a second attack of Chyluria, the first having come on a year previously and lasting some six weeks. He had an enlarged scrotum, which had lasted some seven years; but about six months after the advent of the Chyluria his left foot and ankle began to enlarge, and now they present a well-marked elephantoid appearance—a condition which he referred to as "Goodah" in Bengalee.

About a dozen specimens of blood, obtained by pricking his fingers and toes, were subjected to microscopic examination, and each slide was found to contain two, three, or more specimens.

I will refer to one more instance showing the intimate connection existing between the presence of these Hæmatozoa in the circulation and the elephantoid

fact—for I feel that it cannot be done too strongly nor too often—that the detection of *Filariæ*, whether it be in the urine or in the blood, is sometimes a matter of very considerable difficulty. Hours may have to be spent in examining the sediment of apparently excellent samples of Chylous urine before they are found; fresh supplies may even be required, for the numbers present may vary very much in different samples obtained from the same individual; and, as may be learnt from some of the cases narrated above, they may be even absent for a time from either the urine or the blood, or from both —at all events their detection required more patience than I was able to command at the time of examination, whereas, they were obtained with tolerable ease from the same person on subsequent occasions: I have also observed that, occasionally, they will disappear altogether for some time previous to the disappearance of the Chylous condition of the urine. It will therefore be evident that no great amount of foresight is required to be able to predict that, owing to want of proper appliances, want of time, or other circumstances, such remarks as '*Filariæ* were searched for, but not found,' will, not infrequently, be recorded in connection with reports of Chyluria cases."

* Eighth Annual Report of the Sanitary Commissioner, Appendix E, page 246.

states above described. In May last Dr. Kenneth McLeod, Professor of Anatomy at the Medical College, very kindly forwarded for my examination about three ounces of a reddish-brown fluid, emitting a faint, but not disagreeable, odour, of slightly alkaline re-action, and with a specific gravity of 1·022. After standing awhile the reddish colouring matter partially subsided; the upper layer assumed a chyle-like aspect and formed an imperfect coagulum.

This fluid had exuded through minute orifices from soft tubercular elevations on the surface of the scrotum of a native patient. The scrotum is described as presenting a sponge-like aspect, especially on the left side, and as covered with yielding prominences from which fluid may constantly be squeezed—a condition which appears to have existed about three years. On subjecting the sediment of this fluid to microscopic examination numerous living *Filariæ* were readily detected.

Dr. McLeod has published an account of this in a paper entitled "Remarks on Varix Lymphaticus or Nævoid Elephantiasis," * an essay which is particularly valuable, in that it not only gives a full and accurate description of this case, but in it the literature of the subject has also been carefully collected and analysed.

With regard to the actual mode by which this leakage of nutritive fluid, whether chylous, sanguineous, or a mixture of the two, is produced, it is impossible in the present state of our knowledge to speak with certainty. Formerly, one of the best explanations of a mechanical nature that could be suggested was that of interruption to the flow of the nutritive fluid by the presence of tumours acting directly by pressure upon the lymphatics, or the smaller blood vessels, or indirectly by pressure on nerves, and thus interfering with the nervous supply of the part. The intermittent character, however, of the malady and its recurrence after long intervals of absence could not be explained in this way. One of the classes of the disorder, namely, that in which the sub-cutaneous tissues are affected, might possibly have been explicable by some such supposition as the lesions once produced—the diseased action once established by interference with the nutrition of the part—might become permanent. The repeated recurrence of Chyluria, however, at irregular intervals, would allow of no such simple explanation. And here I fear that Dr. Vandyke Carter's ingenious "regurgitation" theory, as well as Dr. William Roberts's highly original theory of hypertrophy of the lymphatic tissue with subsequent acquisition of gland properties, would, in the ordinary run of the disease, as seen in a tropical climate, equally fail us. Nor would, indeed, the *exacerbations* which various elephantoid maladies frequently manifest be easily explicable on any such assumptions.†

* Indian Medical Gazette, August 1874.

† It would be interesting to know whether the hæmaturia of Egypt, Brazil, etc., present similar, well marked exacerbations, especially as this disease is one well known to be associated with a parasite—the *Bilharzia hæmatobia* of Cobbold. Latterly, moreover, the hæmaturia of Egypt has been found to be associated with the existence of a microscopic nematode in the blood, for Dr. Sonsino discovered two specimens in the blood of a young Egyptian Jew last February. In a communication just received from

When, however, it is considered that tumours may be of parasitic origin, and that they may be in very intimate relation with the vascular system, enclosed in the same fibrous sheath, such as the tumours which may be frequently observed along the aorta in dogs (Plate XXXVIII, Fig. 8), and which may well be conceived as exercising pressure upon the thoracic duct and important nerves, the difficulty of accounting for the erratic character of the disease is much simplified. Such obstructing causes as these need not be permanent, and probably are but so, but, as may readily be supposed, are very prone to recur in the same tissues, as such parasites manifest remarkable tendency to attack a particular organ and even particular parts of it. It is by no means improbable that the mature parasite having deposited its ova or embryos may shift its position and remain quiescent for a time in some out-of-the-way cellular tissue—sub-cutaneous or otherwise.

It will be recollected that the entrance of the *Filaria sanguinolenta* into the blood vessels of the dog was shown to be effected by the migration of young immature worms (not exceeding $\frac{1}{12}$th of an inch in length) from the mucous surface of the œsophagus by perforation of its walls, and subsequently by penetrating the walls of the artery, thereby causing considerable disorganisation of the arterial tissue, and leaving more or less extensive aneurismal sacs as indications of the spots where the worm attained maturity. It is possible, and indeed highly probable, that a somewhat similar course is taken by the mature parasite of which the *Filaria sanguinis hominis* in the circulation is the offspring. It may be that it is not the œsophagus that is pierced and the thoracic aorta specially attacked, for this particular parasite may, perhaps, proceed as far as the duodenum, or still further down the alimentary canal, before it commences to follow its migratory instinct, and then find its way either directly into the aorta or reach the circulation by some other channel, such as one of the mesenteric arteries. So that in this instance the tumours and lesions may be along the walls of the abdominal aorta or its renal and other branches, or even be situate in intimate relation to the *Receptaculum chyli* and the principal lymphatics. It is equally evident that the tissues along the urinary tract may be similarly attacked by the growing and matured parasites—indeed these structures may be specially liable to be invaded by them.

Moreover, since it has been demonstrated that parasites, such as the *Filaria sanguinis hominis* can be detected in the capillary net-work of the blood-vessels, we have become aware of a factor capable of exercising no inconsiderable force compared with the resistance which the delicate walls of the capillaries of the

Dr. Sonsino he expresses his belief that the nematode which he found must be closely related to the *Filaria sanguinis hominis*. A highly interesting account of his observation has been communicated to the Academy of Naples. This fact relating to the hæmaturia of Egypt is particularly interesting, when it is remembered that, some years ago, Dr. Wucherer discovered a microscopic nematode in the urine of a person suffering from the hæmaturia of Brazil—although from the limited information we possess concerning these two parasites it would be quite premature to refer them to the same species.

vascular system generally are capable of withstanding; and when the extremely intimate relation which the capillaries hold to the lymphatic spaces, so carefully described by Dr. Klein,* and the excessive delicacy of the several partitions, are borne in mind, it is not to be wondered at that the urine under such circumstances should contain sanguineous and chylous fluid—the latter seldom or never without some trace of the former; and that extravasations of the same fluids should take place in the scrotum and elsewhere. Possibly these leakages occur far more frequently, and into more organs and tissues than at present imagined—the processes of assimilation, of absorption, and of repair following the injury so quickly and so completely as not to attract special attention to the part.

The fact that these leakages are not limited to the urinary tract is of moment in considering the etiology and pathology of the disorder, inasmuch as it would have been difficult to imagine that rupture and extravasations could only occur in renal tissue or along the lining surfaces of the channels leading from it, for the capillaries have no such limited circulation; although, on the other hand, it might be argued that the urinary tract may have been affected by some such parasite specially localised in its own tissues just as the hepatic and pulmonary tissues have theirs; but the young, at all events, of this *filaria* have a far wider distribution than this.

Whether the mature worms—the parents of the microscopic nematode hæmatozoa in man—also take up their abode in the circulatory fluids, or merely deposit their ova (or embryos if viviparous) in such situations as will eventually lead to their being conveyed into the circulation, is of little moment, for the mischief which large-size worms accomplish when merely lodged in the cavities of the heart and larger blood-vessels, judging from what we know of the *Filaria immitis* and other blood-worms, would seem not to be invariably or even generally of so serious a nature as might have been supposed. The injuries inflicted on the walls of the aorta of the dog by the *Filaria sanguinolenta*, described on a previous page, are of a far more formidable character, and, in all probability, eventually interfere more with the well-being of the victim, than if the parasite had simply perforated the vessel and acquired maturity whilst, possibly, attached to one of the "columnæ" of the heart.

It is difficult to embody in a few words, without risk of misinterpretation, the substance of observations such as the foregoing on what is admitted to be an extremely difficult subject; nevertheless, it might be desired that I should express briefly (1), the chief reasons for the belief that Chyluria and the elephantoid state of the tissues, referred to on a previous page, are associated with the presence of a microscopic Hæmatozoon; and (2), in what manner, such connection being satisfactorily established, this fact can aid us in offering an explanation of the evidence we possess that the disease is due to mechanical interruption to the flow of the nutritive fluid in the capillaries and lymphatics:

(1)—With regard to the first clause, it may be sufficient to state that detailed

* The Anatomy of the Lymphatic System. 1—The Serous Membranes.

histories of a considerable number of individuals affected in this manner have been published by me, and that in all the *Filaria sanguinis hominis* have been detected. I have now traced the *Filaria* to the blood *direct* in eleven, and detected them in one or other of the various tissues and secretions of the body in more than thirty individuals. The history of one of these persons could not be ascertained, but all the others were known to suffer, or to have suffered, from Chyluria, Elephantiasis, or some such closely allied pathological condition.

(2)—With reference to the second clause our knowledge is not so exact, and almost all the inferences have to be drawn from observations made in connection with the Hæmatozoon described in previous pages as occurring in pariah dogs. Judging from what may be seen in these, and from data which the only *post-mortem* examinations which I know to have been made of individuals affected with this parasite, I think that the interference with the flow of fluid in the lymphatic capillaries and smaller blood-vessels may not unreasonably be attributed to one or other of the following causes :—

a. To tumours, produced by encysted mature entozoa along the course of the blood-vessels and lymphatics, impeding the flow of fluid in them by pressure either directly or indirectly by interfering with the functions of the nerves supplied to the part ;

b. To the active migration of the immature, or rather partially matured parasite ; the act of perforating the tissues—nervous or vascular—producing more or less permanent lesions ;

c. To the activity of the liberated embryos in the capillaries causing the rupture of the delicate walls of these channels in which *possibly* ova may have accumulated owing to their size, or an aggregation of active embryos taken place, either accidentally, or by the parent having migrated to the capillary termination of a blood-vessel and there given birth to a brood of microscopic blood-worms. Once the walls of the capillaries have given way the embryos pass into the adjacent lymph channels, the boundaries of which are so extremely delicate as practically to offer no impediment to the further progress of such active organisms. Should the lymphatic spaces be situated in intimate relation with a secreting surface, the escape of the minute *Filariæ* as well as the escape of fluid from the lymphatics with the ordinary secretion of the part, would seem to be a natural consequence.

At present I do not see that the facts at my disposal warrant any further deductions, but I trust that the description of the observations which have been made have been sufficiently clear that readers will be able to judge for themselves how prominent a part such a Hæmatozoon may play in the causation of some of the diseases peculiar to tropical climates.

CALCUTTA,
1874.

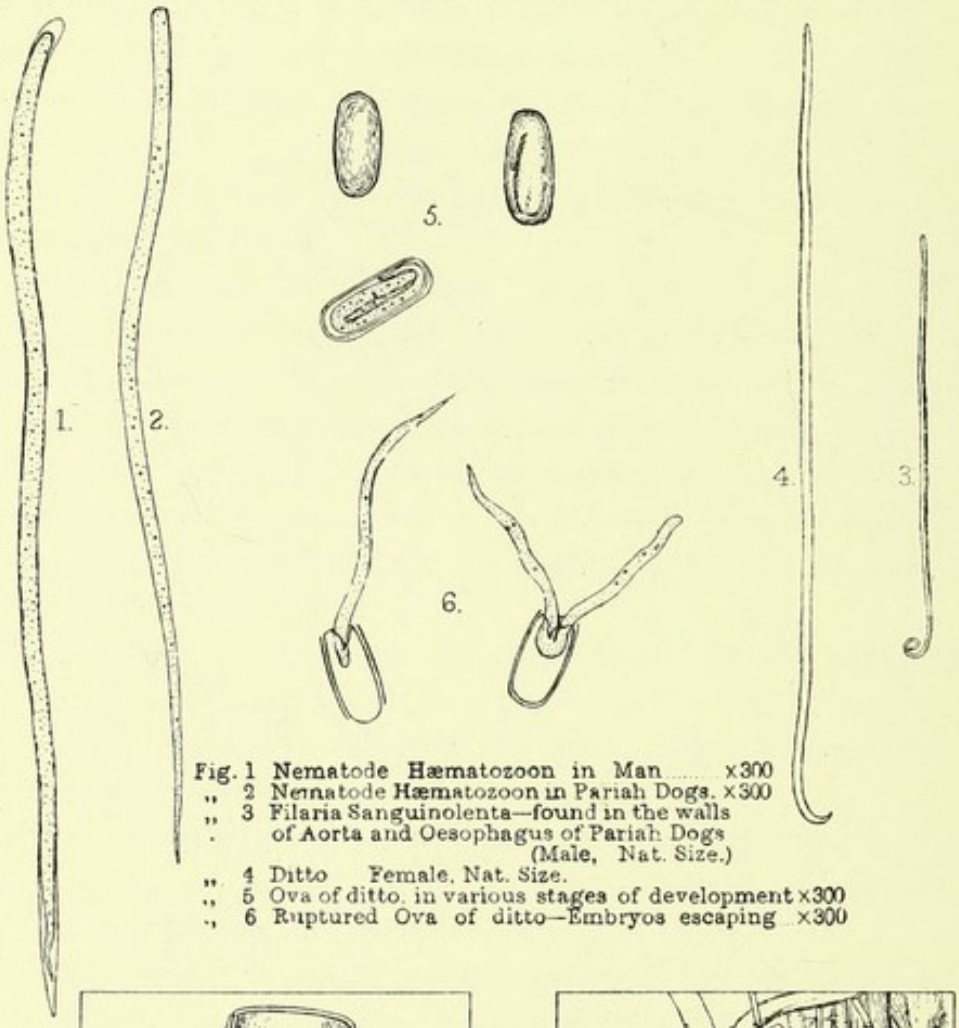


Fig. 1 Nematode Hæmatozoon in Man ..... ×300
" 2 Nematode Hæmatozoon in Pariah Dogs. ×300
" 3 Filaria Sanguinolenta—found in the walls of Aorta and Oesophagus of Pariah Dogs (Male, Nat. Size.)
" 4 Ditto Female. Nat. Size.
" 5 Ova of ditto, in various stages of development ×300
" 6 Ruptured Ova of ditto—Embryos escaping ×300

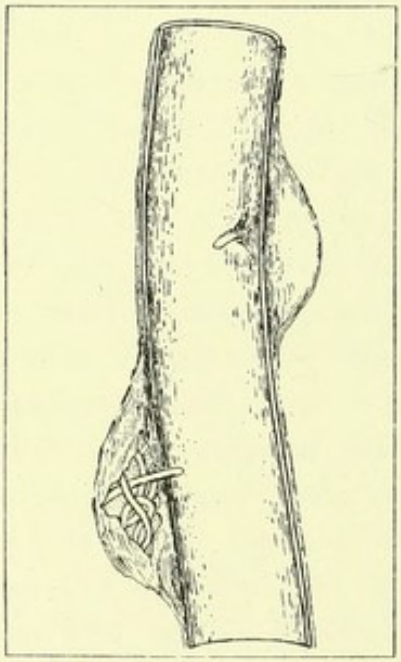


Fig. 7 Section of Aorta of a Dog with Filaria-tumours on its walls; slightly enlarged.

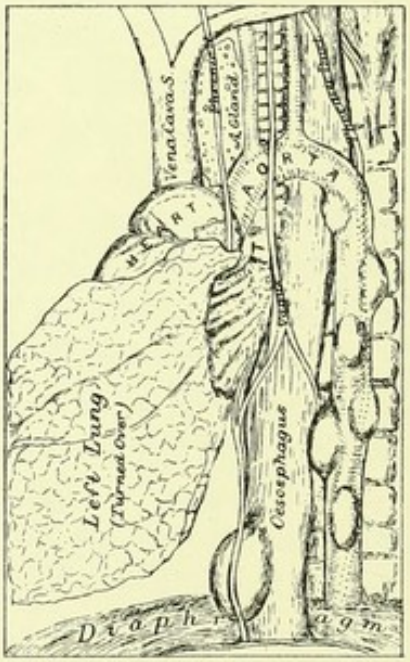


Fig. 8 Sketch of the Thoracic cavity of a Dog, whose blood contained innumerable Hæmatozoa.

T. R. L. ad nat. del.

To face p. 557.

Description of Plate XXXVIII.

Human and Canine Hæmatozoa.

Fig. 1.	Nematode Hæmatozoon (*Filaria sanguinis hominis*) found in man. It is represented as slightly contracted at either end– corresponding portions of the sheath being empty	× 300
„ 2.	Nematode Hæmatozoon as found in pariah dogs. No trace of a sheath visible ...	× 300
„ 3.	Mature *Filaria sanguinolenta;* found in the walls of the aorta and œsophagus of pariah dogs in India, male	Natural size.
„ 4.	Ditto ditto, female	Natural size.
„ 5.	Three ova of ditto ditto, in various stages of development	× 300
„ 6.	Two ova of ditto ditto ruptured by pressure on covering-glass—an embryo is seen to escape from each	× 300
„ 7.	A portion of the aorta of a dog slit open. A mature parasite is seen to be partially projected into the channel of the vessel from each of the tumours. One of the tumours has been cut open	Slightly enlarged
„ 8.	A sketch of the thoracic cavity of a pariah dog whose blood contained Hæmatozoa. Tumours are seen along the course of the aorta and œsophagus—in one place stretching the pneumogastric nerve. The course of the thoracic duct along the aorta is indicated by dotted lines.	

Description of Plate XXXIX.

The development of Filaria Sanguinolenta in the walls of the Aorta of Dogs.

Fig. 9. Longitudinal section of the aorta of a dog. Three, more or less distinctly marked, patches are seen on its inner surface; the lowest, having been dissected under a low power, displays a hair-like parasite ... ... Natural size

„ 10. A portion of the aorta of a dog with parasite-tumours firmly adherent to it. Towards the middle one of the tumours is seen to have been cut into, and a minute worm is distinguishable ... ... Natural size

„ 11. One of the parasites removed from a tumour. The pharynx and œsophagus occupy more than two-thirds of the entire length of the alimentary canal. Reproductive organs not distinguishable ... ... × 12

„ 12. Ditto, ditto, undergoing the process of casting its skin; the old cuticle is seen to have become torn across ... ... × 12

„ 13. As Fig. 11. Shortly previous to the period of moulting. The continuity of the, shortly to be discarded, cuticle, with the termination of the alimentary canal is very evident ... ... × 100

„ 14. Ditto in a more advanced stage of development, the sex having become distinguishable. A young female worm. The vagina is seen to terminate a short distance above the junction of the œsophagus with the intestine, then to divide into two uterine tubes which are seen, in the lower portion of the figure, to be continuous with the ovarian tubules ... ... × 10

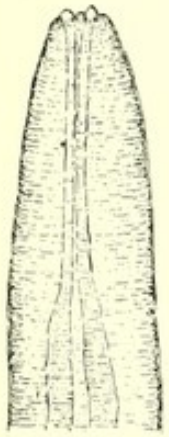
„ 15. A young male worm, nearly mature. The spermatic tube is seen to commence cæcally towards the anterior portion of the parasite and to wind along the intestinal canal until the caudal extremity is reached. The two spicules have also become developed ... ... × 10

Fig. 9.....Nat. Size
Interior of Aorta.

Fig. 10.....Nat. Size
Exterior of Aorta.

Fig. 11.....x12
Immature Worm, removed from a small tumour in the walls of the Aorta.

Fig. 12.....x12
As Fig. 11, but undergoing the process of Moulting.



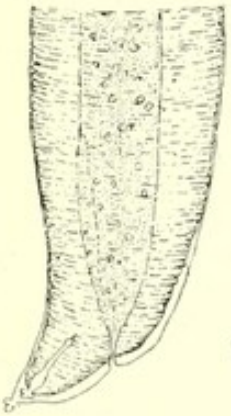


Fig. 13.....100
As Fig. 11 - more highly magnified.

Fig. 14....x10
Young female Worm. Reproductive organs differentiated, but Ova not formed.

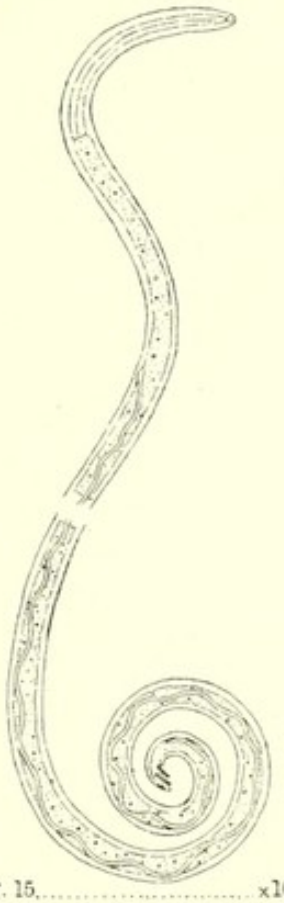


Fig. 15.....x10
Young male Worm. The spermatic tube and spicules distinctly visible.

T. R. L ad nat. del.

To face p. 556.

THE DEVELOPMENT OF FILARIA SANGUINOLENTA IN THE WALLS OF THE AORTA OF DOGS

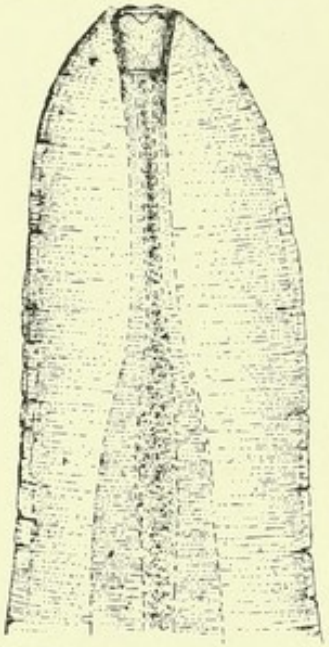
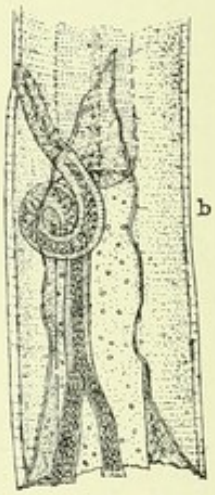


Fig. 16.....×60
Anterior extremity of a mature specimen.

Fig. 17.....×80
Front aspect of mouth

Fig. 18.....×25
Posterior extremity of male. Ventral aspect.



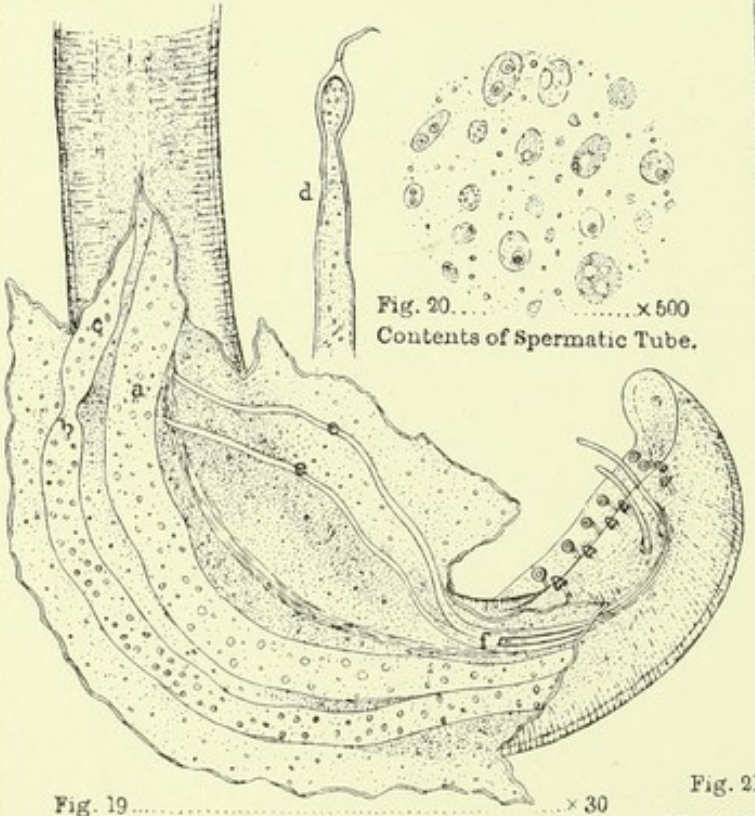


Fig. 19.....×30
Dissection of posterior extremity of male.

Fig. 20.....×500
Contents of Spermatic Tube.

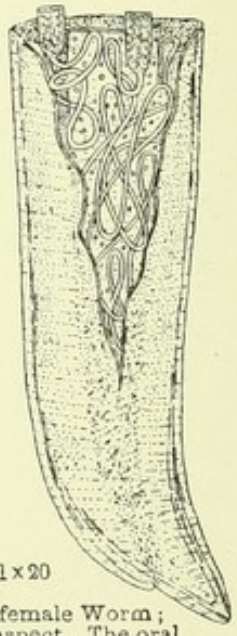


Fig. 21×20
Mature female Worm; lateral aspect. The oral extremity altered by immersion in spirit.

T. R. L. ad nat. del.

To face p. 559.

Description of Plate XL.

Fig. 16. Anterior extremity of a mature *Filaria sanguinolenta*, showing the lateral aspect of the mouth, the pharynx and upper portion of the œsophagus ... ... × 60

„ 17. The mouth as seen from the front, with its six minute "lips" and chitinous pharynx ... × 80

„ 18. Caudal extremity of the male. Ventral aspect. Two spicules are seen of unequal length, with eight pre-anal and four post-anal papillæ... ... ... × 25

„ 19. A dissection of the posterior extremity of the male. The cuticular and muscular coverings have been divided and the various organs exposed:—*a* Intestinal tube:—*b Vas deferens* separated by a sphincterlike constriction from the *testis* (*c*); the cæcal extremity of this tubule is represented separately at *d*: *e e* Retractor muscles of the longer spicule (*f*) ... × 30

„ 20. Cellular bodies pressed out of the spermatic tube ... ... × 500

„ 21. Three portions of a mature female *Filaria sanguinolenta*:—

a. Anterior portion, the outline of the mouth altered through separation of the cuticle by the action of spirit.

b. Termination of genital tube; the vagina, twisted on itself, is seen lying alongside the intestinal canal immediately below the junction of the latter with the œsophagus. It is distended with ova and divides into the two uterine tubes.

c. Caudal extremity: The two uterine tubes with cellular contents, are observed to terminate abruptly in minute tubules (the ovarian) which form coils around the lower portion of the alimentary canal ... ... × 20

THE

MICROSCOPIC ORGANISMS

FOUND IN THE BLOOD OF MAN AND ANIMALS,

AND

THEIR RELATION TO DISEASE.*

BY

T. R. LEWIS, M.B.

INTRODUCTION.

A FEW years ago my colleague, Dr. Douglas Cunningham, submitted a report on the microscopic organisms found in the air,† and embodied, in the account of his own observations, a brief summary of the principal facts which had been recorded by previous writers. An attempt will be made here to deal in a similar manner with the minute organisms which have from time to time been found in the blood of man and animals.

The space at my disposal precludes the possibility of giving anything like a complete account of all that has been written on the subject; the bibliography alone would occupy very many pages, for during recent years no medical subject has occupied more attention that the relation which may possibly exist between living organisms in the blood and some of the most fatal diseases. All that will be attempted will therefore be to give an abstract of what the actual workers in this department of research have observed, and of the conclusions which they have arrived at as the result of personal observation. An account of my own inquiries in the same direction will also be given as shortly as possible.

From earliest times physicians have been accustomed to attribute various diseases to abnormal conditions of the blood, the blood being the connecting link between all the tissues of the body and the external world, furnishing them with the nutriment

* Appeared as an Appendix to the *Fourteenth Annual Report of the Sanitary Commissioner with the Government of India*, 1878.

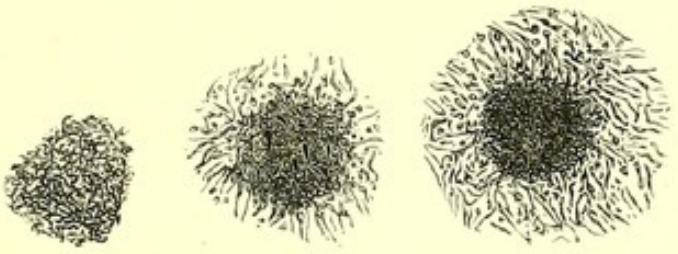
† "Microscopic Examinations of Air:" Appendix A., *Ninth Annual Report of the Sanitary Commissioner with the Government of India*, 1873.

which they require, whether in liquid or gaseous form, and removing from them such products of change as are not required for the efficient exercise of their functions.

The circulation may become the habitat of minute organisms belonging to either the vegetable or animal kingdom, as also to that group of organisms so closely related to both as to render it, in the present state of our knowledge, impossible to say definitely to which they belong—the group which Professor Häckel has proposed to regard as a third organic kingdom and has termed *Protista*.

It will, however, be convenient in the present paper to assume, for purposes of classification, that the organisms which have been found in the blood are either plants or animals.

Before adopting such a classification, however, it may be as well to mention that from time to time various particulate objects have been described as occurring in the blood in regard to which no sufficient evidence yet exists to warrant their recognition as independent beings. These have been generally described as connected with certain



A B C

Fig. 36.—Development of organisms in human blood (Hartnack's Ocular 3, Objective 7).

A. A mass from healthy blood at 10 A. M.
B. Ditto ditto at 10-30 A. M.
C. Ditto ditto at 11 A. M.

(After Osler.)

diseases, but bodies of an allied character are, not uncommonly, found associated with no perceptible disturbance of the normal condition.

Bodies of the latter kind have recently been very carefully described by Dr. William Osler.* They had, however, long before this, been the subject of controversy among pathologists, Max Schultze, L. Riess, and many others having contributed towards our knowledge of their character. The bodies in question are granular masses, composed of aggregations of corpuscular elements, and not uncommonly referred to as "micrococcus colonies" (Fig. 36, A). As Dr. Osler says, "There are probably few observers in the habit of examining blood who have not at some time or other been puzzled for an explanation of their presence and nature. They are particularly plentiful in the blood of fœtal and newly born animals." Max Schultze considered that they are derived from the degenerated white corpuscles of the blood. Riess is of a like opinion. Osler, however, considers them to be organisms in the *liquor sanguinis*, basing his opinion

* An Account of Certain Organisms occurring in *Liquor sanguinis*.—*Proceedings of the Royal Society*, 1874.

on the circumstance that certain changes take place in the masses when a saline solution ($\frac{1}{2}$ or $\frac{3}{4}$ per cent.) or fresh serum is added to them, and the preparation kept at a temperature of about 37° C. Along the margins of the masses (which previously presented a tolerably even appearance) there gradually appear fine projections "which may be either perfectly straight or each may present an oval swelling (Fig. 36, B). These projecting filaments soon present a waving motion and finally break off from the mass, moving away free in the fluid, and in a short time the whole area for some distance from the margins is alive with moving forms (Fig. 36, C). . . . The variety of forms increases as the development goes on; and whereas, at first, spermatozoon-like or spindle-shaped corpuscles were almost exclusively to be seen, later more irregular forms appear, possessing two, three, or even more, tail-like processes of extreme delicacy. The more active ones wander towards the periphery, pass out of the field, and become lost among the blood-corpuscles. The process reaches its height within $2\frac{1}{2}$ hours, and from this time begins almost imperceptibly to decline; the area about the mass is less densely occupied by the moving forms and by degrees becomes clearer, till at last, after six or seven hours (often less), scarcely an element is to be seen in the field, and a granular body, in which a few corpuscles yet exist, is all that remains of the mass." In 1872, Dr. Douglas Cunningham and myself described and figured somewhat similar masses in connection with a description of the changes undergone by the blood in cholera,* but we did not notice anything to suggest that the molecular and filamentous particles manifested independent movements.

It is possible that the bodies described by Dr. Osler may ultimately prove to be closely related to those which were described by MM. Béchamp and Estor in 1869 and termed *Microzyma sanguinis*. In that year these distinguished *savants* announced to the French Academy † that, as the result of numerous observations, they had ascertained that the blood of all animals contained an infinite number of mobile molecules. These were found to be particularly plentiful in the blood of very young animals and especially in blood which yielded a small proportion of fibrine. These microzymæ, on being added to starch or to cane sugar, etc., and placed under suitable conditions as to temperature and so forth, set up fermentation, and, in doing so, gradually became transformed into beaded, filamentous, stellate bodies, and bacteroid rods: the last named were seen to become detached from a heap of such rods and to move in a characteristic manner. They continued to multiply so long as sufficient nourishment remained in the fluid. Moreover, they were described as retaining their vitality after prolonged boiling in creosoted distilled water. Somewhat similar mobile bodies were described by Medsvetzki a few years later and named *hæmococci*.‡

* A Report of Microscopical and Physiological Researches: Appendix A., *Eighth Annual Report of the Sanitary Commissioner with the Government of India*, and reprinted in this volume, p. 65.

† *Comptes Rendus*, t. lxix, p. 713.

‡ Schmidt's *Jahrbücher*, vol. clix, p. 181.

In 1872, M. Arloing submitted an account of the result of his investigations as to the real nature of the *Microzyma sanguinis*, and showed pretty conclusively that no such thing as proliferation of these bodies occurred; that whereas proliferation required some time, these could be produced instantaneously under certain conditions by treating the blood with alcohol, and that consequently the supposed organisms were the result of simple chemical action;—the explanation being that the hæmato-globuline, having been removed from the blood-corpuscles by the action of water, was subsequently precipitated by the action of alcohol. The addition of tannin to a mixture of blood and lukewarm water produced a similar result. The stellate appearance presented by some of the masses, described as organisms in process of formation, was due to granules adherent to the remains of blood-corpuscles.

Six or seven years ago a considerable stir was created in the medical circles of Vienna by the announcement that characteristic molecular bodies had been discovered in the blood of syphilitic patients by Lostorfer, and that these were so constantly present as to be diagnostic of the disease.* After some months of discussion in various learned societies as to whether these "syphilis-corpuscles" were fungi-micrococci (for these also during "cultivations" arranged themselves into threads), oil globules, or the remains of degenerated white corpuscles, Biesiadecki announced, as the result of numerous experiments, that the bodies in question were precipitated particles of paraglobulin.

I.—THE ORGANISMS OF A VEGETABLE NATURE WHICH HAVE BEEN FOUND IN THE BLOOD.

BEFORE entering on a minute description of the microscopic organisms found in the blood which are more allied to plants than to animals, it will be advantageous to consider to what special subdivisions of the vegetable kingdom these bodies seem to belong. No small amount of confusion has arisen from want of a clear knowledge of this point, especially on the part of strictly medical writers who have discussed the subject of the connection of disease with vegetable parasites. Nägeli, in his remarkably suggestive work,† recently published, has placed this matter in a very clear light, and, being an authority of the first rank, especially on the botanical phase of the subject which forms the text of this paper, his statements on this particular point are worthy of exceptional attention. The forms of plant-life which have been recognised as having been more or less closely associated with changes in living animal substances are the lower kinds of fungi. These, Nägeli separates into three groups; (1) *Moulds*, characterised by

* Stricker's *Medicinische Jahrbücher*, Heft 1, 1872.

† *Die Niederen Pilze in ihren Beziehungen zu den Infectionskrankheiten und der Gesundheitspflege*, München. 1877.

branched, segmented or unsegmented filaments; (2) *Sprouting-fungi*, yeast cells of various kinds, consisting of more or less oval corpuscles which multiply by means of sprouts from their surfaces; and (3) *Cleft-fungi* or *Schizomycetes*—minute spherical or oval bodies which are multiplied by fission only, and which sometimes remain isolated, at others form unbranched rows (rods, threads, etc.), but only occasionally present a cubiform aspect. To this group the *bacterium*, *vibrio*, *vibrio-bacillus*, *spirillum*, etc., belong.

Nägeli writes: "I have separated the lower forms of fungi into three groups. On account of many practical questions it is of importance to know whether specific differences really exist, or whether we have to do with the same species under different conditions, it being possible that different fungi possessed a 'mould,' a 'sprout,' or a 'cleft' form. This is a subject which has formed the subject of debate during the last sixteen years, and many observations have been recorded for the purpose of showing that, as a result of cultivation-experiments, the most opposite forms have been seen to pass from one into the other." With reference to this point Nägeli forcibly points out the fallacies to which men are liable in drawing conclusions from cultivation-experiments, and says that, in many respects, it would be as rational for the husbandman to assert that the weeds in his field were the result of transformation which the seed of wheat previously sown had undergone. No one would believe such a statement, for the seeds of weeds are large enough to be easily recognised, whereas the germs of fungi are of microscopic dimensions—those of the *schizomycetes* often barely distinguishable with the highest powers: hence the assertions which have been made regarding the transition of such minute organisms cannot easily be controlled. "Moreover," adds Nägeli, "the rapid and superficial observer has a marked advantage: the conclusions which he has arrived at as the result of a so-called uncontaminated cultivation [*Reinkultur*] of a single week's duration may require years of labour on the part of the thoroughly competent observer to disprove."

This question has of late years been investigated by many distinguished *savants*, notably by Professor de Bary of Strasburg. He has shown that a fungus undergoes but a very limited and well-defined range of changes. Nageli, as the result of his own observations, declares that, of the three groups of fungi above referred to, the "mould" and "sprout" fungi are closely related, but that, with one exception, they have not yet been seen to pass from one form into the other. The exception consists in the circumstance that a certain species of mucor (a mould) has been observed to present the two forms of vegetation—the filamentous and the sprouting. Fission-fungi, however, do not stand in any genetic relation to either of the other two groups, for they neither give rise to other fungal forms nor originate from them: hence it is distinctly laid down that they do not germinate. In this it would appear that Nägeli and de Bary are completely in accord. Nägeli states that it is comparatively easy to demonstrate that the "fission" group of fungi are not transformed into other groups from the circumstance that members of the latter when present in a solution are killed at a lower temperature

than those of the former. This peculiarity, however, renders it much more difficult to show that other (the "mould" and "sprout") groups do not give rise to *schizomycetes*, as it is impossible so to isolate the germs of other fungi as to exclude this group. Eventually, however, he was able to satisfy himself on this point also by first destroying by heat all the fungal forms in a nutrient solution, and then permitting a mould to extend its filaments into it. In this way he kept some solutions thus prepared for four years with only the "mould" form of vegetation in them.

Of the foregoing three groups of organisms, the only one which requires to be dealt with here is the third—the *schizomycetes*—as it is only the various forms of this group of the fungal family which have hitherto been unequivocally found in the blood.

Another distinguished botanist, Professor Cohn of Breslau, has also paid much attention to these low forms of life, and has recently devised a new system of classification for them, taking as his starting point the dictum that the *schizomycetes* are more closely related to *algæ* than to fungi, and suggests, therefore, the term *schizophytæ* for the family in place of the name given by Nägeli which has been in general use hitherto. Cohn has, moreover, advanced the supposed differences in physiological properties manifested by some of these low growths as sufficient grounds for assigning to them specific designations. In doing this, Nägeli says, Cohn has given expression to a generally entertained opinion and one especially affected by the medical profession, but he (Nägeli) is unacquainted with any facts in support of such a view. "I have," he writes, "during the last ten years examined some thousands of different forms of fission-yeast cells, but (excluding *sarcinæ*) I could not assert that there was any necessity to separate them into even two specific kinds." * On the other hand, there is not sufficient evidence to show that all the forms constitute in reality but one species.†

Notwithstanding the circumstances that the *schizomycetes* assume, within certain limits, such different aspects (and the experience of such an authority as Nägeli on such a matter as this cannot be lightly set aside) it is nevertheless convenient, irrespective of any particular theories, that terms should be adopted which will suffice to distinguish the leading forms.

Dujardin suggested three terms for the group: (1) *bacterium*, (2) *vibrio*, and (3) *spirillum*. Notwithstanding the great advance which has been made in our knowledge of these organisms since the date of Dujardin's classification, there still remains very much to be done before anything like a satisfactory settlement of the matter can be accomplished. It will, therefore, perhaps be better for the present to accept these simple terms, especially as, with very trifling modifications, they are sufficient to indicate all the forms which have hitherto been found in the blood. The following brief description will suffice to explain what forms of this group of organisms are comprehended by the terms adopted: 1, *Spherical bacteria*—minute, vitalised bodies, barely visible with the highest powers (fig. 37, A); 2, *Elongated bacteria*—almost equally minute cylindrical

* Op. cit., p. 20.

† Op. cit., p. 22. Also A. de Bary, "Ueber Schimmel und Hefe," 1869.

rods (Fig. 37, B); 3, *Vibriones*, short, undulating filaments manifesting somewhat screw-like movements (Fig. 37, C); 4, *Bacilli*, or *Vibrio-bacilli*—fine, short filaments, indistinctly jointed, which, when they attain considerable length, are sometimes described as *leptothrix* filaments (Fig. 37, D); 5, *Spirilla*—fine, more or less flexible, spiral filaments, which manifest well-marked screw-like movements (Fig. 37, E).

It may be mentioned, in passing, that examples of each of these forms may, commonly, be detected in the muco-salivary fluid from the mouth of healthy persons.

The question which naturally suggests itself now is: Under what condition are organisms of this character found in the blood? M. Pasteur states that the blood in health is absolutely free from anything of the kind. His words are: "Le sang d'un animal en pleine santé ne renferme jamais d'organismes microscopiques ni leurs germes." * Dr. Beale, on the other hand, says, "The higher life is, I think, interpenetrated, as it were, by the lowest life. Probably there is not a tissue in which these germs are not;

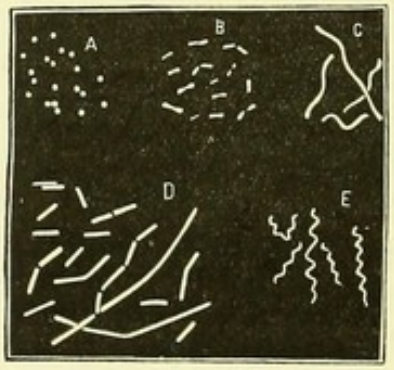


Fig. 37.—Various forms of Fission-fungi—*Schizomycetes* × 600 diam.
A. Spherical bacteria (*Bacterium punctum*).
B. Elongated bacteria (*Bacterium termo*).
C. Vibriones.
D. Bacilli.
E. Spirilla.

nor is the blood of man free from them." † It may appear strange that the satisfactory settlement of a question, apparently so very simple, should hitherto have proved impossible and that many eminent observers should have arrived at opposite conclusions regarding it. It may be that to a certain extent both classes of observers are in the right, for if, as is not uncommonly affirmed, very many of these extremely minute organisms constantly find their way into the circulation through the lungs and pass through the walls of the intestinal tract along with the food (that *bacteria* pass with fluids through a membranous septum is a well-ascertained fact, as also that they will pass through porous earthenware and other filtering media), it is very certain that their existence in the plasma of healthy blood is of comparatively short duration.

This point has been definitely settled as the result of observation by many patho-

* *Comptes Rendus*, t. lxxxv, p. 108; 16th July, 1877.
† *Disease Germs*, 1870, p. 64.

logists, and Dr. Douglas Cunningham and myself were, some years ago, able to satisfy ourselves that *bacteria*, *vibriones*, *bacilli*, and so forth very speedily disappear from the *liquor sanguinis*, even when introduced into it during life in considerable numbers. Out of forty-nine experiments which were conducted by us with a view of clearing up this matter, twelve of the animals were examined within six hours of the organisms being injected into the veins, and *bacteria*, etc., were found to be present in seven, or at the rate of about 58 per cent.; and out of thirty examined within twenty-four hours, their presence was detected in fourteen, or 47 per cent.; whereas in nineteen specimens of blood derived from animals which had been inoculated in this manner from two to seven days previously, these bodies could only be detected in two of them, or a little over 10 per cent., just 6 per cent. higher than we had observed to be the case out of a number of ordinary preparations of healthy blood which we had examined.* It is, however, obvious that though it is possible that the blood may be constantly replenished with a greater or less number of these organisms, yet they do not accumulate to any great extent therein, and it may be safely affirmed that their presence in appreciable numbers is, judging from experience, incompatible with a state of perfect health. It will hereafter be seen that the same remark does not hold good as regards parasites of, apparently, animal nature.

It may be affirmed, further, that in certain diseased conditions microphytes are very generally present, though perhaps not invariably, nor is their number co-incident with the gravity of the malady. Omitting the cases in which these organisms have been found associated with disease in insects (on account of the difficulty of isolating and clearly identifying such organisms as are found in the blood in these cases, from those found in the tissues generally), it may be stated that it has been clearly established that one or other of the forms of fission-fungi have been found in the blood in two diseases, *viz.*, in *charbon*, *mal de rate* or *splenic fever;* and in *recurrent fever*. M. Pasteur has recently maintained that a third should be added to the list—*septicæmia;* and, still more recently, a fourth has been added by Dr. Klein, namely, the disease commonly known as "*typhoid fever*" of the pig.

These matters have, during the last few years, received great attention from thoughtful members of the medical profession, and probably at the present time no subject of a scientific character is being more closely investigated.

The importance of thoroughly sifting the evidence on which the interpretations which have been placed on the significance of such organisms in the blood can scarcely be overrated, seeing that, should the views now commonly advanced proved to be correct, the theory and practice of medicine would be radically affected, and, possibly, the future action of the state with regard to disease be materially modified. Before making an attempt to institute such an examination, it may be well to

* Cholera: A Report of Microscopical and Physiological Researches, Series I. Appendix A, *Eighth Annual Report of the Sanitary Commissioner with the Government of India*, 1872, reprinted here, p. 65.

refer briefly to the more salient circumstances which have conduced to make the present doctrine of the causative relation to disease of these low forms of plant-life so attractive to botanists and to the medical profession. "The foundations of the germ theory of disease in its most commonly accepted form," writes Dr. Charlton Bastian,* "were laid in 1836 and shortly afterwards. The discovery at this time of the yeast-plant by Schwann and Cagniard-Latour soon led to the more general recognition of the almost constant association of certain low organisms with different kinds of fermentations. But it was not till twenty years afterwards that Pasteur announced, as the result of his apparently conclusive researches, that low organisms acted as the invariable causes of fermentations and putrefactions; that such changes, in fact, though chemical processes, were only capable of being initiated by the agency of living units." These observations and the interpretations applied to them very rapidly caught the ear of the medical profession, as from a very early period in the history of medicine the supposition that disease was propagated by means of a ferment—a leaven—had taken a firm hold. Previous to the publication of M. Pasteur's observations, a physico-chemical theory had been almost universally acknowledged as sufficiently explanatory of the phenomena manifested by certain classes of disease. This was notably the case with regard to the fermentation-doctrine of Liebig, a doctrine the truth of which he strongly advocated until the day of his death in 1873, and which, somewhat modified as a result of later researches, is still upheld by some of the most eminent chemists of our own time.

The leading features of the "vital" and the "physico-chemical" theories of fermentation† have recently been lucidly summarised by Mr. C. T. Kingzett in a paper read before the Society of Arts.‡ With regard to the first of these views and in illustration of them this chemist remarks: "When a solution of sugar is exposed to the action of the healthy yeast it suffers a change; the atoms comprised in its molecules are broken up and re-arranged into new forms which are recognised as alcohol and carbonic dioxide. Glycerine and succinic acid are also formed at the expense of the sugar, but the lactic acid which generally accompanies alcoholic fermentation is considered as proved to be due to the presence of a ferment distinct from, but accompanying, the yeast. . . . The fermentation alluded to is regarded as a particular instance of a biological re-action, manifesting itself as the result of a

* Paper read before the Pathological Society of London, April 6th, 1875. *Lancet*, vol. i, page 501, 1875. *British Medical Journal*, vol. i, page 469, 1875.

† "Certain organic compounds, when exposed to the action of the air, water, and a certain temperature, undergo decomposition, consisting either in a slow combustion or oxidation by the surrounding air, or in a new arrangement of the elements of the compound in different proportions (often with assimilation of the elements of water), and the consequent formation of new products. The former process, that of slow combustion, is called *Eremacausis* or *Decay;* the latter is called *Putrefaction* or *Fermentation—putrefaction*, when it is accompanied by an offensive odour, *fermentation*, when no such odour is evolved, and especially if the process results in the formation of useful products; thus, the decomposition of a dead body, or of a quantity of blood or urine, is putrefaction; that of grape-juice or malt-wort, which yields alcohol, is fermentation."—*Watt's Dictionary of Chemistry*, vol. ii, p. 624, 1872.

‡ *Journal of the Society of Arts*, March 1878.

special force residing in organisms; or, in other words, fermentation is essentially a correlative phenomenon of a vital act, beginning and ending with it. On this hypothesis, where there is fermentation there is organisation, development and multiplication of the globules of the ferment itself. The instance quoted above is by no means solitary; it is exemplary of many other changes, induced by the same or other fermented matters in media suitable for their growth and reproduction. Thus, we have mannitic, lactic, ammoniacal and butyric fermentations, besides many others, all of them having one feature in common, *viz.*, the reproduction of the ferment.* It has not yet, however, been satisfactorily ascertained—a very essential matter to be settled before the foregoing interpretation of fermentative processes can be established—that the several processes are the result of the action of specifically distinct growths.

Baron Liebig vigorously opposed this doctrine, and, Mr. Kingzett suggests, probably ignored the influence, of vital action to too great an extent; all that was required in his opinion for inducing the fermentative change was contact with matter which was itself undergoing change. Mr. Kingzett thus sums up the physico-chemical doctrine of fermentation as advanced by Liebig: Mechanical or other motion exerts an influence on the power which determines the state of a body. Thus, a crystal of sulphate of sodium, a speck of dust, or grain of sand, when dropped into a saturated solution, say of sulphate of sodium, may determine the entire crystallisation of the fluid. Or, again, when fulminates of silver and mercury are tickled lightly by a feather or glass rod, they suddenly explode with violence. A still better instance is the re-action which occurs between peroxide of hydrogen and argentic oxide; these substances, when mixed, give rise to the production of metallic silver and free oxygen: the peroxide of hydrogen, being unstable, is constantly undergoing decomposition from the moment of its formation, and this decomposition results in the production of water and free oxygen; immediately, therefore, that this change comes into contact with oxide of silver, it gives to that body the same tendency to change.

A.—The Organisms found in the Blood in Splenic Fever.

On the assumption that certain diseases which are undoubtedly communicable by inoculation, and several others commonly believed to be communicable in other ways, are in reality the result of a ferment of some kind, the various theories of the causation of the fermentative processes have always proved an attractive subject of study to the more thinking section of the medical profession. As already stated, the physico-chemical theory of Berzelius, and subsequently of Liebig and his followers, was very commonly accepted as fairly sufficient in connection with the etiology of disease, so long as it was favourably received by the majority of the chemists of the time; but latterly Schwann's views, as expounded and amplified by

* *Journal of the Society of Arts*, March 1878.

Pasteur and others, have undoubtedly taken the lead. Probably no single incident has tended so much towards enlisting the attention of the medical profession to it than the publication of the experiments of M. Davaine, which went to show that minute organisms were, to a greater or less degree, constantly present in the blood of animals which had died of the disease known as malignant pustule in man—the "*Milzbrand*," of Germany; the "*charbon*" of cattle and pigs, and "*mal de rate*" of sheep, in France. The terms "splenic fever" or "splenic apoplexy," "anthracoid disease," etc., are commonly adopted in England in describing the affection. Birch-Hirschfeld* states that the organisms found in this affection were first described by Brauell in 1849 and by Pollender in 1857; but, undoubtedly, it was M. Davaine's researches which were the means of drawing serious public attention to the matter. In August 1850 M. Davaine, in conjunction with M. Rayer, published an account of these organisms, describing them as minute filamentous bodies, motionless, and about double the length of the diameter of a red blood-corpuscle. M. Pasteur† maintains that the time just mentioned represents the date of the first publication of the existence of these bodies in charbon, but this idea is manifestly erroneous.

Instigated thereto by the publication of M. Pasteur's researches (which went to show that butyric fermentation was not, as believed, due to an albuminoid body in process of spontaneous decomposition, but to vibriones, which presented the greatest resemblance to the "corps filiformes," found in the blood of animals dying of *charbon*) M. Davaine returned to the subject in 1863 and 1864. The organisms were at first considered by M. Davaine to be bacteria; but finding in certain cases that the filaments or rods varied in length, he modified the name, and they have consequently been, until lately, commonly designated *bacteridia*. At this period it was supposed that they were more closely related to animals than to plants. He satisfied himself that they were found in the blood during life; that they developed in this fluid and not in the spleen; in fact, he had been able to transfer the organisms to animals whose spleen had been removed. He also ascertained that bacteridia are not found in fœtal blood, although the blood of the mother and of the placenta was crowded with them.‡ The disease was found to be communicable with the food by mixing with it some of the tissues of diseased animals; the effects were less rapily induced, but the blood became equally affected with bacteridia. He refuses to accept the doctrine of identity of the poison of septicæmia and charbon, on the grounds (1) that the symptoms produced by inoculating animals with putrefying blood are not constantly the same, and that bacteridia do not develop in the circulation of the affected animal; (2) that animals which have swallowed fragments of putrefied tissue rarely died; and (3) that animals which had swallowed fragments of the fresh tissues of animals which had died of septicæmia had been in

* Schmidt's *Jahrbücher der gesammten medicin*, Band 166, S. 205, 1875.

† Etude sur la maladie charbonneuse; par MM. Pasteur et Joubert. *Comptes Rendus*, t. lxxxiv, p. 900, 1877.

‡ *Comptes Rendus*, t. lix, p. 393, 1864.

no way affected. He therefore concluded that the active principle of septicæmia was not regenerated in the animal economy as in the case of charbon, the latter in fact being a *virus* and the former a *poison.**

In the following number of the *Comptes Rendus* (p. 429), MM. Davaine and Raimbert announce that they had demonstrated the existence of bacteridia in a man affected with *pustule maligne*, the excised pustule having contained a great number.† Portions of this pustule-tissue having been introduced beneath the skin of some animals, the latter succumbed, and after their death their blood was found to contain a considerable number of bacteridia.

Such, in a few words, were the observations which drew the special attention of pathologists to this question, and gave marked impetus to the doctrine of disease germs. Since this time very many observations have been recorded, but those of the past two or three years have been particularly valuable from the circumstance that distinct parts of the subject have been taken up by observers peculiarly qualified to deal with the different phases of the extremely complex phenomena which come under notice. In the first instance, notice will be taken of the principal observations which are considered to give support to MM. Davaine and Pasteur's views.

In 1875 Professor Ferdinand Cohn published the result of his examinations of these organisms, and having pronounced them to be *bacilli*, suggested that they should bear the name *Bacillus anthracis.*‡ This term has been generally adopted in Germany and England, as, notwithstanding the theory implied in both words, it is convenient to have some such brief designation. Cohn's figure of this bacillus is reproduced (Fig. 38), as a graphic representation from the hand of so accomplished a mycologist is of special value, and will serve to aid in forming an estimate of the relation of these organisms to others found under other, though somewhat similar, conditions.

Fig. 38.—*Bacillus anthracis*, obtained after death, in the blood of an ox which had died of splenic disease. (After Cohn.) × 600 diam.

In 1876 an important contribution to our knowledge of these organisms was published by Dr. Koch of Wollstein (Posen), who had had excellent opportunities of studying the disease.§ Koch had observed that several of the statements and conclusions of M. Davaine had been called in question. Some observers had been

* Loc. cit., p. 396. As will subsequently be seen, some of these conclusions are no longer tenable.

† Dr. Crisp writes: "As I described in my work on the spleen (1852), dogs, cats, ferrets and pigs, that ate the flesh of these animals, died in a short time, and men that flayed the oxen were affected. In 1832 M. Barthelemy inoculated sheep from the blood of sheep that died of splenic apoplexy, and the inoculated animals died in from thirty-six to sixty hours."—A footnote to the Remarks made regarding the "Germ Theory" at the Pathological Society, 24th April, 1875.

‡ Cohn's *Beiträge zur Biologie der Pflanzen*, Band I, Heft 3, 1875.

§ Cohn's *Beiträge*, Band II, Heft 2.

able to induce fatal *charbon* by inoculating animals with bacteridial blood without obtaining any bacteridia* in the blood of the animal thus affected, although the latter (bacteridia-free) blood had also induced the disease, and, moreover, given rise to bacteridia in the third animal, although none had been present in the second. Others, again, maintained that the disease was not due solely to contagion, but was, somehow, dependent on the soil, seeing that the disease was only endemic in moist, swampy districts, valleys and sea-coasts; and that the mortality was greater in rainy years, and especially during August and September, months in which the temperature of the soil reached its highest. The circumstances could not be explained on Davaine's supposition that the organisms, retaining their vitality for a long time in dry air, were conveyed by air currents, or that inoculation was effected by insects, and so forth. Koch's experiments led him to believe that Davaine's explanation of the mode of propagation of the disease is only partially correct. He found that bacteridia-staves were not so hardy as Davaine had supposed. Blood which contains only rods will retain its property in the dry state for but a few weeks, and when moist only for a few days. How, therefore, could the contagion remain dormant in the soil for months and years? If bacteridia had anything to do with the matter, it must be assumed that during some stages of their development they were inert, or that, as Cohn had suggested,† *resting spores* were formed which had the power of retaining their vitality for a long time, and of giving rise anew to bacteridia. The existence of such spores is what Dr. Koch believes he has been able to demonstrate. As this question is a very important one, it is necessary that the evidence adduced should be submitted to careful examination.

The experiments of Davaine and others were repeated, mice having been found to furnish the most satisfactory results. The tail was seized, and a small portion of its skin being abraded, a drop of the fluid containing the bacilli was placed in contact with the small wound. Such inoculations proved to be invariably fatal when fresh material was used. In order partly to ascertain whether the bacilli passed into some other form by successive inoculations, and also to provide himself with a constant supply of fresh material, he inoculated one mouse after another, the last mouse supplying the material for its successor, until eventually a series of twenty inoculations had been conducted: consequently twenty crops of bacilli had been cultivated without any marked change in their character being noticeable.‡ The pathological results were always of the same character—enlarged spleen, and *motionless*, translucent bacilli (Fig. 39). The latter in mice were more numerous in the spleen than in the blood, but different animals showed different results as regards their distribution in the tissues—the blood of inoculated rabbits, for example, being often so free from them as to be traced with difficulty, though the spleen and glands

* Cohn's *Beiträge*, Band II, Heft 2.

† Cohn's *Beiträge*, Band I, Heft 3.

‡ Davaine had conducted a similar series of inoculations.

contained plenty, whereas in guinea-pigs the number of bacilli in the blood was often so great as to equal, if not exceed, that of the red blood-corpuscles.

On adding a little of the spleen affected with bacilli to perfectly fresh aqueous humor and subjecting the preparation to a temperature of 35-37° C. for from 15 to 20 hours, the bacilli became elongated to from twice to eight times their original length, and gradually still further increased, till more than a hundred times this length (Fig. 40). Some of the filaments were now finely granular, and, here and there, dotted with strongly refractive molecules, which are believed to be the desired "resting-spores." Very soon nothing remained visible but these "spores," as the filament appeared to undergo solution, but the persistence of the arrangement of the former in rows is sufficiently marked to identify them. They will remain unaltered in this state for several weeks.

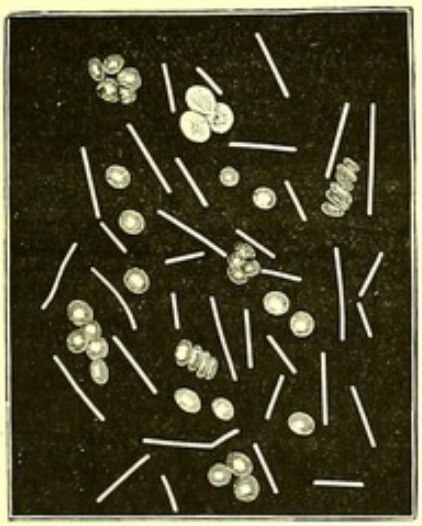


Fig. 39.—*Bacillus anthracis* from the blood of a guinea-pig: Translucent bacillus-rods, undergoing segmentation. Blood-corpuscles are scattered throughout the field. (After Koch.) × 650 diam.

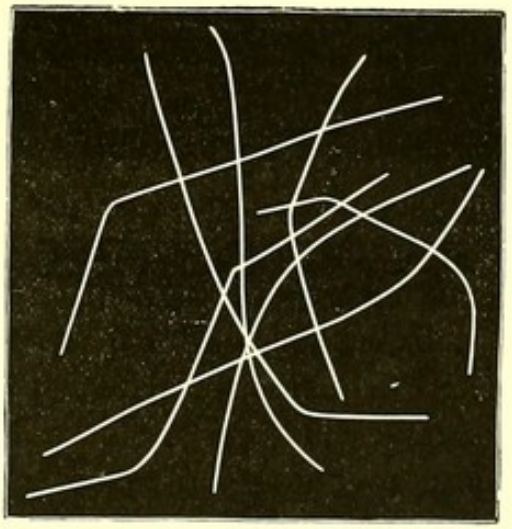


Fig. 40.—*Bacillus Anthracis* from the spleen of a mouse after a 3-hour "cultivation" in a drop of aqueous humor. (After Koch.) × 650 diam.

It will be remarked that the interpretation placed on the character of these refringent bodies clashes with what is so strongly maintained by Nägeli, who, as mentioned already, declares emphatically that the group of lower organisms to which these belong multiply *solely* by fission. It is, therefore, of greater importance to note precisely what the facts adduced are, to prove that in this special instance germinating *spores* are produced.

Dr. Koch states that the fact of his being able to induce splenic fever, together with a plentiful crop of bacilli in the blood, with fluid in which not a trace of a bacillus filament is any longer to be found—the minute refractive corpuscles alone remaining, is proof sufficient to show that the latter are in reality *spores*, and not products of disintegration merely. Cultivation-experiments were, however, also undertaken, and it was found that in the course of 3 to 4 hours the development of these

bodies could be observed under suitable conditions. On careful examination each "spore" is seen to be an oval-shaped body embedded in a translucent substance which appears to surround the former in a ring-like fashion, but is seen to be in reality spherical, on being rolled over. This substance loses its spherical form and becomes elongated at one end in the direction of a long axis of the contained "spore." The latter remains at one end, and very soon the translucent tube assumes a filamentous aspect and, contemporaneously, the "spore" becomes less refringent, pale and small, and possibly breaks down into fragments, until it eventually disappears completely.* Dr. Koch's figure (Fig. 41), representing the various stages of the supposed germination-process, is reproduced.

This interpretation of what occurs is made particularly important from the fact that it has been resorted to very lately by M. Pasteur to account for the circumstance that, although it has been proved, beyond all reasonable doubt, that splenic fever, together with blood-bacilli, may be induced by inoculation with virus after the total destruction of the filament-bacillus which the morbid material had contained, yet because the "spores" remained (it would seem that they are considered nearly

Fig. 41.—*Bacillus Anthracis:* Germination of the spores. (After Koch.) × 650 diam.

Fig. 42.—*Bacillus anthracis:* Germination of the spores. (After Cohn.) × 1,650 diam.

indestructible) the virus had retained its property—the "spores" in fact being the virus.

Professor Cohn favoured Dr. Koch with a sketch of the same developmental process as seen under a higher power. This figure is also reproduced for purposes of comparison. Koch suggests that probably the "spore" consists of a strongly refractive substance, probably oil, which is enveloped by a thin layer of protoplasm—the latter being the substance capable of germination, and the former, perhaps, serving as nourishment during the germinating process. The foregoing, according to various writers, represents the complete cycle of development undergone by *Bacillus anthracis.*

Davaine, it will be recollected, had found that animals eating diseased tissues mixed up with their food became themselves affected, and he believed that the spread of the disease could thus to some extent be easily accounted for. Koch, on the contrary, finds that animals very susceptible to infection by inoculation, such as mice and rabbits, may devour such a mixture with impunity. Attempts to inoculate two dogs, a partridge, and a sparrow, proved fruitless.

* Loc. cit., p. 289.

The latest contribution which has been made towards this inquiry is from the pen of Dr. J. Cossar Ewart.* Dr. Ewart confirms Dr. Koch's experiments in many points, and his description of the development of the rods into filaments [Fig. 43, and Fig. 44, (*a*)] corresponds with that of previous writers; but his description and figures of the germination of the "spores" are totally different. "The spores," writes Dr. Ewart, "when free, according to previous observers, at once grow into rods, and, according to Koch at least, the rod is formed out of a gelatinous-looking envelope surrounding the spore. My observations lead me to believe that the spore does not always at once grow into a rod, but that it divides into four sporules by a process of division,

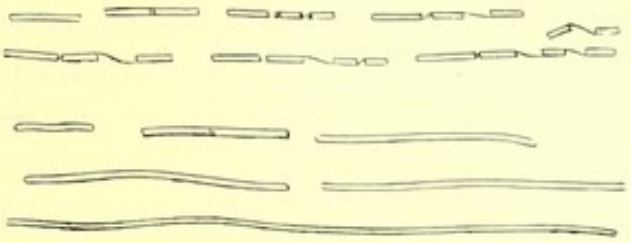


Fig. 43.—*Bacillus anthracis:* Rods undergoing segmentation and lengthening into a filament. (After Ewart.) × ? diam.

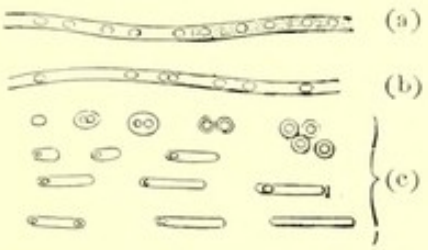


Fig. 44.—*Bacillus anthracis:* (a) A filament containing spores, becoming granular at one end, and showing transverse lines between the spores; (b) Part of a filament containing a spore in process of division; (c) shows the different stages through which a spore passes in its development into a rod. (After Ewart.) × ? diam.

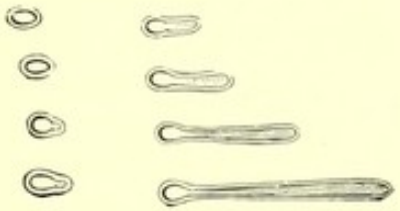


Fig. 45.—*Bacillus anthracis:* A sporule developing into a rod. (After Ewart.) × ? diam.

in which the envelope as well as the spore takes part. This division I have seen beginning before the spore escaped from the filament [Fig. 44, b], and that it is not a degeneration is certain, for I have watched the sporules thus formed lengthen into rods [Fig. 44, (c)]. Dr. Koch states that the rods are developed from the gelatinous-looking capsule, and not from the bright, shining spore. From what I have seen I think there can be no doubt whatever that the capsule takes no active part during the formation of the rod. The sporule thus slightly elongates [Fig. 45], and then from one of its poles an opaque process appears, which, as it slowly lengthens, pushes the capsule before it, as it would an elastic membrane. The capsule, as this stretching goes on,

* *Quarterly Journal of Microscopical Science*, April 1878, p. 161.

becomes at last so thin and transparent that it can no longer be distinguished from its contents."

It is, I think, extremely probable that MM. Cohn and Koch may suggest as an explanation of the discrepancy between their description and figures and those given by Dr. Ewart, that the latter has described and figured the spore (or conidium) of a totally different plant, accidentally present; and MM. Nägeli and de Bary would (in the absence of exact data as to size) in all probability pronounce the germination depicted in the last figure reproduced as being that of a conidium of one or other of our ubiquitous moulds.

Like Koch, Dr. Ewart found that mice could be fed with splenic-disease material mixed with their food without any evil effects ensuing, and that "the spores may be found in the alimentary canal of such mice, sometimes as if in process of development into rods and filaments." With reference to the last remark, a person constantly engaged in microscopic work may question whether it is possible to distinguish these glistening free "spores" from the myriads of other glistening molecules found in the intestinal canal of all animals.

Contrary to the results hitherto obtained and published by others in support of the view that *bacillus anthracis* is itself the specific virus of splenic fever, Dr. Ewart finds that the filaments are *not* absolutely motionless, but that, at certain stages, they manifest active movements, so that the strongest argument which has hitherto been adduced in favour of these organisms being a peculiar species has disappeared.*

Dr. Ewart found also that the bacilli of splenic fever in guinea-pigs differed in size from similar bodies in affected mice, the bacilli of the former being always longer than those of the latter. It was also ascertained that the bacilli and their "spores" were killed after being boiled for only two minutes, the fluid after this treatment becoming absolutely inert. A like result ensued on similar fluid being subjected to a pressure of twelve atmospheres of oxygen.† Considering the position into which the supporters of the germ doctrine had latterly been driven by their antagonists, the announcement made above regarding the instability of the "spores" will be unwelcome and none the less so by the circumstance of its having been made by one of their warm adherents.

A few years ago Mons. P. Bert announced that he had ascertained that compressed oxygen rapidly kills all living beings and tissues. He had paid special attention to ferments in the investigations which he had conducted and had satisfied himself that

* Since this was written I have observed that A. Frisch had on three occasions seen independent movements of the staves of *Bacillus anthracis* in blood obtained immediately after the death of the animals.—*Centralblatt fur die wissensch. Medicin*, April 7, 1877, page 247.

† Since this was in type a note has appeared in the *Comptes Rendus* (15th July, 1878) which confirms this observation. M. Felz found that compressed oxygen if applied for a sufficiently long period killed the "germs" as well as the "vibriones" of septic solutions.

such of the fermentation-processes as were dependent on living matter were immediately suspended when subjected to this influence, whereas those fermentations which were due to some material in solution, such as diastase, pancreatine, myrosine, emulsine, etc., were in no way affected. He then turned his attention to certain poisons secreted in health or disease in animals, the venomous secretion of the scorpion, vaccine matter, etc.*

The venom of the scorpion, whether liquid or dried and re-dissolved in water, resisted the action of compressed oxygen, as was expected, since it owes its activity to a chemical substance akin to the vegetable alkaloids. Fresh liquid vaccine matter was submitted for a week to the action of compressed oxygen and still retained its power undiminished. Pus from a case of glanders after being subjected to similar treatment rapidly killed a horse inoculated with it; hence M. Bert infers that the active principle in vaccine and in glanders is not a living being or living cell.

M. Bert then exposed some blood from a case of splenic fever (in which were myriads of bacilli) to the action of compressed oxygen, and found that, although the blood had been exposed in very thin layers, it had retained its virulent properties intact, as was proved by its having killed several guinea-pigs inoculated one from the other, but the blood of these animals did not contain bacilli.

He submitted some other charbon-blood containing numerous bacilli to further examination. Some absolute alcohol was very cautiously added to it, drop by drop, until the volume of the original fluid was quadrupled, and the mixture thus obtained was filtered. The coagulum, well washed in alcohol, was rapidly dried *in vacuo*. A fragment of this dried material, on being inserted beneath the skin of a guinea-pig, killed the animal in less than twenty-four hours. The blood obtained from this animal proved fatal to another guinea-pig, as also to a dog. Inoculations were conducted from one animal to another, but the virulent blood of none of these animals contained bacilli.

M. Bert went still further. A watery solution was prepared (by exhaustion) of the alcoholic precipitate, and having satisfied himself that this liquid contained the active principle in solution (for, on the addition of more alcohol, a white flocculent precipitate was induced), three successive inoculations of guinea-pigs were conducted. This rather severe treatment, however, had manifestly diminished the virulence of the material, as inoculation was not successful beyond the third animal, and the material proved too weak to kill a dog.

From these observations M. Bert concluded that the blood in splenic fever contains a toxic and virulent principle, which resists the action of compressed oxygen and can be isolated in the same manner as diastase.

These observations had been published in an abbreviated form previous to their being submitted to the Academy.† M. Pasteur had promptly taken up the subject,

* *Comptes Rendus*, t. lxxxiv, p. 1130, May 1877.

† *Comptes Rendus de la Societé de Biologie*, January 1877.

and, as he himself was not versed in the medical and veterinary arts, had associated himself with M. Joubert of the Collége Rollin for the purpose of more satisfactorily dealing with the matter. Their joint paper* was published a few weeks before the publication of the *details* of M. Bert's experiments; it was their remarks, indeed, which led to the latter being published. They obtained charbon-blood and made numerous cultivations of it—transplanting it from vessel to vessel or from animal to animal. Outside the body it was found that almost any fluid adapted to the nourishment of minute organisms was suitable to the cultivation of the bacilli—"one of the best and most easily obtained in a pure state being urine made neutral or slightly alkaline." In this way, it is affirmed, poisonous bacilli could be prepared by the kilogram, if required, in the course of a few hours. When the material was filtered, the clear fluid was found to be inert, even though from ten to eighty drops were taken, whereas a single drop of the same unfiltered proved fatal to the inoculated animal: hence it is inferred that the organisms were left behind on the filter and were the cause of their death.†

The foregoing paper was followed by another in July 1877‡ by the same authors, in which it is stated that they had repeated M. Bert's experiments and found that he was perfectly correct as to the destruction of the bacilli and of the poisonous property of charbon blood at a certain stage under the influence of compressed oxygen, and that, too, even with but a moderate amount of pressure; but that when the bacilli had proceeded to the formation of *spores*, they withstood the heat of boiling water, the prolonged action of absolute alcohol, as also the influence of compressed oxygen (=10 atmospheres for 21 days). The "spores," therefore, are most remarkable organisms, seeing that they withstand influences which are destructive to every other form of vegetable or animal life. True "invisible germs" are accredited with this marvellous power, but, as yet these "spores" are the only *visible* bodies for which such persistent vitality has been claimed by eminent authorities. Now, however, that it has been shown by Dr. Cossar Ewart that they are not more exempt from "the tendency to death" than other organisms of a like kind, seeing that they can neither withstand the action of compressed oxygen nor boiling, it is probable that MM. Pasteur, Koch, and their adherents will apply the doctrine at present fashionable, and aver that, though

* *Comptes Rendus*, t. lxxxiv, p. 900, April 1877.

† A similar result was obtained by M. Onimus, but the interpretation was very different. M. Onimus found that if the blood of an ox, horse, or person suffering from "typhoid fever," be placed in a dialyser, and the latter placed in distilled water at a temperature of 35° C., a prodigious quantity of organisms would appear, identical in appearance with those in the putrefying blood. But whereas all the animals which were inoculated with a drop of the blood contained in the dialyser died in a short time, those which were treated with the dialysed material (though crowded with organisms) were unaffected. The same result followed when putrefying blood from a rabbit was subjected to similar treatment. Hence M. Onimus infers that the poisonous material is an albuminoid substance, and therefore not dialysable (*Bulletin de l'Académie de Médicine*, March 1873. Cited by M. Ch. Robin in *Leçons sur les Humeurs*, p. 251, 1874). Clementi and Thin, Schmitz, Bergmann and others, have obtained more or less similar results.

‡ *Comptes Rendus*, t. lxxxv, p. 101.

the "spores" may be dead, their invisible germs still live, and, under favourable circumstances, will re-appear.

With the foregoing explanation as to the difference between bacilli and their "spores," in their power of withstanding agencies ordinarily destructive to life, M. Pasteur was able to convince his former pupil, M. Bert, of the cause of the discrepancies in their respective results, and this the more readily from the circumstance that when a little of the dried alcoholic precipitate of charbon-blood was placed in urine the fluid not only manifested virulent properties, but also gave rise to a plentiful crop of bacillus-filaments identical in appearance with those which had existed in the blood previous to its being treated with alcohol.

It does not seem to have occurred either to M. Pasteur or to M. Bert that under certain circumstances the addition of any dried organic substance to suitable urine would probably be followed by a crop of bacillus. Indeed, it not unfrequently happens that such a crop may be obtained without intentionally adding anything.

Whilst this paper was in preparation it occurred to me to place such a sample of urine under different conditions as to temperature, etc., and to carefully observe the results. Some specimens were made slightly alkaline, others made neutral, and others again left untouched. All the specimens were kept at temperatures varying from 35° to 40° C. (95° to 104° Fahr.), and it was found on the following day that nearly half the specimens were coated with a thin pellicle consisting of bacilli in all stages of development, the spore-stage included, notwithstanding that considerable care had been taken to keep out particles and foreign matter of every description. These appearances are familiar to all who have devoted much attention to microscopic studies. It need hardly be added that organisms thus obtained would produce no effect on animals if freed from the decomposed urine.

B.—The Vegetable Organisms in Septicæmia.

The belief that septicæmia is produced by organisms belonging to the lower group of fungi has had almost as many adherents as the doctrine just considered, and the literature in support of it is even more extensive. The virus secreted by animals suffering from this disease is, when transferred to the circulation of other animals, as fatal in its results as that of charbon. It can, moreover, be transferred from animal to animal * almost indefinitely. The symptoms induced by such inoculation are frequently so very like those witnessed in splenic fever that it is often impossible satisfactorily to distinguish them. There is, however, this marked distinction, namely, that whereas the presence of organisms in the blood before

* Observations illustrative of this have long been known. Hamont, for example, in 1827 injected matter from a gangrenous abscess from one horse to another and from the inoculated horse to a second horse, and found that death resulted with pretty much the same symptoms in both cases.—MM. Coze and Feltz, in *Les Maladies Infectieuses*, p. 58, 1872.

death is, to a greater or less extent, the rule in what is known as charbon, it is the exception in septic poisoning. The fluid exuded into the peritoneal cavity, and frequently also into the pericardial sac, is peculiarly prone to give rise to the development of various forms of fission-fungi, and the abundance with which they are sometimes found very shortly after death has given rise to the doctrine that they were the initiatory agencies by which the fatal results were produced.

The publication of Panum's experiments, which went to show that the active morbid principle in such fluids could not by any possibility be vitalised, served for a time to diminish the popularity of such views, but they have since been revived again and again, and never with a greater show of circumstantiality than has recently been the case in a paper submitted by MM. Pasteur and Joubert before the French Academy. This paper, notwithstanding that it exceeded the prescribed length, was, on account of the importance attached to it by the Academy, published *in extenso.**

The paper deals in the first place with M. Bert's experiments, and explains the discrepancies between M. Bert and M. Davaine's results in connection with charbon-blood, as already described. But it goes further than this. It will be recollected that the toxic material submitted to experiments by M. Bert did not give rise to bacilli in the blood, although its virulent properties were most marked, and the possibility of inoculating the disease from animal to animal without bacilli was quite as manifest as in charbon-fluid crowded with them. Similar results have been published by many observers; for instance, MM. Jaillard and Laplat did so very soon after Dr. Davaine's paper was read in 1863, and formulated their conclusions in this wise: (1) charbon is not a parasitic disease; (2) the presence of bacteridia is to be considered as an epi-phenomenon, and not as a cause; and (3) that the fewer bacteridia the blood in *sang de rate* contains, the more virulent it is. It thus became common to hear of cases of charbon with, and cases without, bacteridia.

Davaine has also shown that the virulent properties of the virus of septicæmia manifest a marked increase when transferred from animal to animal. It had been found that after twenty-five such successive inoculations, a millionth, and even a billionth or trillionth, part of the original poison was sufficient to produce death. Rabbits were found to be very susceptible; guinea-pigs somewhat less so. Rats were found to be capable of resisting a considerable quantity. It was also observed by Davaine that decomposing blood lost its virulent properties when exposed to the air in a few days; out of 27 animals inoculated with 1 to $\frac{1}{100}$th of a drop of blood, which had stood from 1 to 10 days, 12 died, whereas out of 26 animals inoculated with like material which had stood from 11 to 60 days only 1 perished.†

* *Comptes Rendus*, t. lxxxv, p. 101, 16th July, 1877.

† "Inoculation de la matière septique:" *Bulletin de l'Académie de Science*, November 1872, January 1873; cited by Birch-Hirschfeld, loc. cit., page 173.

M. Pasteur, bearing in mind the difference between bacilli of charbon and their "spores" as regards tenacity of life, determined to ascertain whether a similar condition did not exist in septicæmia. Three animals which had died of charbon were examined —a sheep, dead 6 hours; a horse, dead 20 to 24 hours; and a cow, dead over 48 hours. The blood of the sheep, which had only recently died, contained charbon-bacteridia only; that of the horse bacteridia, together with "*vibrions de putréfaction*;" whereas that of the cow contained *only* "vibrions" of the kind last mentioned.

Inoculations with the blood of all three animals were followed by death. The autopsies (conducted immediately after death) of the guinea-pigs which had died after inoculation with material from the two last-mentioned animals, revealed extensive inflammation of the muscles of the abdomen and limbs, with accumulations of gas here and there, the liver and lungs discoloured, the spleen normal in size, but often diffluent; the blood of the heart not coagulated, although this characteristic was more evident in the liver—quite as evident as in any case of charbon. Strange to say, writes M. Pasteur, the inflamed muscles contained mobile "vibrions;" these were still more numerous in the serosity of the abdominal cavity, and some of them were of great length.* A drop of this fluid would rapidly kill an inoculated animal, but ten or twenty had no effect after it had been filtered. The "vibrions" are not found in the *blood* till after or very shortly before death, and such blood is said to manifest no virulent properties if taken direct from the heart without contamination with the tissues outside it.

The movements of these "vibrions" were stopped on subjecting them to the action of compressed oxygen, but they were not killed, because on coming into contact with the oxygen they were transformed into *corpuscles-germes*, the "spores" of Dr. Koch. This, it may be remarked in passing, is a novel and rapid method of producing reproductive elements in plants.

Not only do these "vibrions" of septicæmia withstand the action of compressed oxygen, or rather become transferred by its action from perishable filaments to apparently imperishable *corpuscles-germes*, but they, like the "spores" in charbon, also withstand the action of absolute alcohol. Hence, M. Pasteur infers that septicæmia, as well as charbon, is caused by organisms—the parasite of the former being mobile, but that of the latter not.

It will be more convenient to analyse these results hereafter.

C.—Vegetable Organisms in Pneumo-enteritis "Typhoid-fever"—of the Pig.

In February of the present year Dr. E. Klein, F.R.S., brought before the Royal Society a portion of the result of an experimental inquiry (which had been conducted

* M. Pasteur, on noticing this condition, asks why it is that a circumstance so general in deaths of this kind had hitherto escaped notice; and replies to the query, that it was doubtless owing to the attention of previous observers having been devoted solely to the blood. It seems strange that M. Pasteur's specially selected *collaborateur*, and adviser in medical matters, did not inform him that this very appearance was about the best known of all the phenomena characterising septic poisoning.

for the Medical Officer of the Local Government Board) into the etiology of a disease sometimes described as typhoid fever of the pig, also as hog plague, *mal rouge*, red soldier and malignant erysipelas. Dr. Klein, however, proposes to show that the disease is not typhoid fever, nor anthrax, but an infectious disease of its own kind, which he proposes to call "infectious pneumo-enteritis" of the pig (*Pneumo-enteritis contagiosa*).* The disease appears to present considerable pathological resemblance to septicæmia and to charbon, except that, as regards the latter, the fresh blood does not, as a rule, contain any foreign matter, and in most instances does not possess any infectious property. Of five animals inoculated with the fresh blood, one only was affected, but the specimen of blood which produced this retained its activity when closed in a capillary tube for several weeks. The peritoneal exudation, however, always contains the virus in an active state, and solid lymph obtained from such an exudation will, if dried at about 38° C., prove active. This accords pretty closely with what has usually been observed in septicæmia. Inoculation can also be effected by means of portions of diseased lung, intestine, or spleen, as also with the frothy sanguinous exudation in the bronchi, and infection may take place when the virus is introduced directly into the stomach.

It would seem that like organisms were discovered by Leisering some eighteen years ago, in apparently the same affection of the pig as that now described by Dr. Klein.

Dr. Falke, in referring to the bacilli of splenic-fever, and after alluding to the circumstance that Delafond had been able to induce the disease in other animals by inoculating them with $\frac{1}{20}$th of a drop of bacillus-blood, states that Leisering, in his Dresden Report for 1860, mentions that it is quite correct that such bacilli are found in the blood in splenic disease, but that he (Leisering) had also found that they were present in four pigs which had suffered from well-marked typhus (abdominalis) with ulcers in the intestines and swelled follicles.† There is no indication here that the bacilli seen by Dr. Leisering in pig-typhoid differed in appearance from those which he had seen in charbon; on the contrary, he seems to assume that they are identical, and hence questions their being pathognomonic of the latter disease.

Seven cultivation-experiments were conducted by Dr. Klein of the bacilli observed by him, "to prove that the virus can be cultivated artificially, *i.e.*, outside the body of the animal." Minute portions of peritoneal exudation were added to aqueous humor

* "Experimental Contribution to the Etiology of Infectious Diseases with special reference to the Doctrine of Contagium Vivum:" *Quarterly Journal of Microscopical Science*, April 1878, p. 170.

† "Bericht über die Thierarzneiwissenschaft," Schmidt's *Jahrbücher*. Band 114, p. 131. The original is as follows: "Leisering sagt im Dresdner Bericht f. 1860, dass man nach den vorliegenden Beobachtungen mit Recht annehmen könne, dass im Milzbrandblute diese eigenthümlichen Körperchen stets vorkommen. Er habe jedoch dieselben auch bei vier Schweinen gefunden, welche an ausgeprägtem Typhus litten, der mit Darmgeschwüren geschwelten Follikeln, blassgraulicher Färbung der Musklen und keiner Blutüberfüllung der Eingeweide einherging."—Cited by Professor Klob in his *Pathologisch-Anatomische Studien über das Wesen des Cholera-Processes:* Leipzig, 1867.

on a glass slide in the usual manner and kept at temperatures ranging from 32° to 39° C. for a day or two; then a portion of the cultivated substance was transferred to a second slide with fresh aqueous humor, and so on, till from a third to an eighth generation was reached. With material thus obtained seven animals were inoculated at different stages of the cultivations. All the animals are described as having been affected, but it would appear that death did not result. Doubtless further information as to the symptoms, etc., manifested by the inoculated pigs will be furnished when full details of the experiments are published. In the meantime it may, however, be noted that it is not mentioned that bacilli were found in the blood of the inoculated animals.

Dr. Klein states that the cultivated liquids proved, on microscopic examination, to be "the seat of the growth and development of a kind of bacterium which has all

Fig. 46. Fig. 47. Fig. 48.

Fig. 46.—The Bacillus of infectious *Pneumo-enteritis* of the pig, cultivated in aqueous humor of rabbit, showing spores germinating into rods, isolated rods, and series of rods.

Fig. 47.—From a similar specimen, as in Fig. 46, at a later stage; most of the rods have grown into long filaments.

Fig. 48.—Showing the formation of bright cylindrical spores in the filaments at a later stage

The drawings are represented as the objects appear when seen under a Zeiss's F. objective, and Hartnack's III eye-piece, fitted to a Hartnack's small stand. (After Klein.)

the characters of *Bacillus subtilis* (Cohn)"—a figure of which, copied from Cohn's paper, will be found on another page (Fig. 49). The rods of the pig-*bacillus* (Fig. 46) are referred to as being thinner than those described by Cohn as occurring in hay solutions, also thinner than those of the *Bacillus anthracis*, and, unlike the latter (according to Davaine, Pasteur, Koch, and others) possess a moving stage.* It will, however, be recollected that Dr. Ewart has shown that *Bacillus anthracis* may also manifest very active movements. Under favourable circumstances the filaments grow into leptothrix-like filaments (Fig. 47) just as other bacilli are known to do.

"In these filaments," writes Dr. Klein, "highly refractive spores make their appearance (Fig. 48). These become free after the disintegration of the original

* The letters A, B, used in the original figures (as given in the Microscopical Journal) appear to have become accidentally transposed by the lithographer, as what is referred to in the text under "A, Bacillus of infectious *Pneumo-enteritis* of the pig, cultivated in *aqueous humor*, showing spores germinating into rods, isolated rods and series of rods," evidently refers to B in the plate, and not to the figure marked A.

filamentous matrix. The fully developed spores of our bacillus differ from those of hay-bacillus and anthrax bacillus by being more distinctly cylindrical and much smaller." In a footnote it is mentioned that in the figures accompanying Koch's first paper in Cohn's *Beiträge* (1876) "the spores are represented in many places as more or less spherical in shape;" but if the very valuable micro-photographs of these bodies accompanying Koch's subsequent paper* be referred to, it will be found that the "spores" are very decidedly of a long-oval form. The pig-bacillus "spores" have according to Klein a long diameter of 0·0005 mm., whereas those of *anthrax* = 0·0015—·002 mm. "At first," writes Dr. Klein, "I misinterpreted the spores, regarding them as a kind of *micrococci*, and only after repeated observations have I succeeded in tracing them through their different stages of development." Unfortunately, Dr. Klein has not detailed the grounds on which this very important statement is based, nor are figures given. It can scarcely be supposed that any of the figures in the plate are intended to represent the germination of a particular spore. As this distinguished observer well knows, it is not what takes place before the supposed germination, or after it, which has been the subject of debate for so many years in connection with the development of the *schizomycetes*, but the act itself. None of the figures furnished by Dr. Klein present any resemblance to Dr. Ewart's germination-figure (Fig. 45, page 575) in which this process is unmistakably depicted, but some of them are somewhat like those of Koch (Fig. 41, page 574); on the other hand, Dr. Klein writes regarding the conclusions of the observer who first ventured to pronounce these bodies in *Bacillus athracis* to be spores, "I entirely differ from Dr. Koch with regard to the mode of germination of the spores of bacillus." The points of difference are matters of secondary moment and need not be specially referred to here.

Dr. Klein concludes his paper thus: "Seeing that splenic fever, pneumo-enteritis, and specific septicæmia possess a great affinity in anatomical respects, and seeing that in splenic fever and pneumo-enteritis there is a definite species of bacillus,—the difference of species being sufficiently great to account for the differences in the two diseases,—we may with some probability expect that *also* the third of the group, *viz.*, specific septicæmia, *is due to a bacillus*.† This, however, remains to be demonstrated."

Dr. Klein, therefore, believes that whilst the evidence adduced by himself in support of the cause of pneumo-enteritis in the pig being a bacillus is sufficient to warrant a positive statement in the affirmative, that adduced by Davaine, Pasteur, and others in favour of a like cause for septicæmia is not.

D.—The Vegetable Organisms in the Blood in Recurrent Fever.

There is one other disease in which vegetable organisms have been found in the blood, namely, recurrent fever (*Febris* or *Typhus recurrens*). In this affection also the organisms belong to the lower fungi-group, the *schizomycetæ*,—that is to say, the

* Cohn's *Beiträge*, Band 11, Heft 3, Taf. xvi, 1877.

† The italics are mine.—T. R. L.

fungi which multiply by cleavage, in contradistinction to the groups which multiply (1) by sprouting or (2) by germination. The fission-fungi, however, present themselves in this disease in a different form from that witnessed in the preceding, anthracoid, class of affections. In the latter the organisms recognisable range from the spherical bacterium to the bacillus or vibrio-bacillus form,—the bacillus being by far the predominating form; but in recurrent fever the representative of the *schizomycetes* is a *spirillum*—a form of the fission-fungi which, so far as I am aware, has not hitherto been detected in any of the anthracoid affections referred to in the preceding pages.

We owe the discovery of this organism in the blood to Virchow's former assistant, the late Dr. Obermeier. They were found in the blood and also in the mouth of persons suffering from this form of fever, and minutely described by him in 1873.* It would appear that this observer had already seen them as far back as 1868. In all the cases observed by him they were present in the blood during the height of the fever, but were absent during the remission or intermission, as the case might be; nor were they observed, except rarely, after the crisis. Obermeier describes them as fine fibrine-like threads, equal in length to the diameter of from $1\frac{1}{2}$ to 6 red blood-corpuscles; and manifesting screw-like, progressive movements, which may continue from one to eight hours after removal from the body. The inoculative experiments which he undertook, consisting of the injection of spirillum-blood of fever patients into the veins of dogs, rabbits, and guinea-pigs, proved abortive, nor was there any effect produced by the injection, by means of a subcutaneous syringe, of small quantities of such blood into the bodies of healthy persons.

Obermeier's observations as to the existence of the spirilla in blood in this kind of fever were speedily confirmed by numerous observers, and the negative results which followed his attempts at inoculating persons and animals likewise characterised the attempts of several who followed in his footsteps. Motschutkowsky, however, states that, although he also had failed to inoculate animals, yet he had succeeded in inoculating persons with the blood of patients suffering from the fever, no matter whether it contained spirilla or not.†

It was, however, soon found that whereas spirilla could generally be detected in cases of fever of this kind, nevertheless cases every now and then occurred in which perfectly competent observers failed to detect them in the blood from first to last, and this too, in cases not a whit less severe than those in which the organisms abounded and which were under the care of the same observers during the same period.

Some discrepancy exists in the results of different observers as to the presence of spirilla during apyrexia periods, as well as regards their absence during the height of the paroxysm; Birch-Hirschfeld, for example, observed them two days after the crisis;‡ and Laskousky, basing his observations on thirty-two cases, says that they

* *Centralblatt für die medicinische Wissenschaften*, No. 10, March 1873, and in subsequent numbers during the same year.

† Heydenreich: "Ueber den Parasiten des Rückfallstyphus," S. 38, 1877.

‡ Schmidt's *Jahrbücher*, Band 116, S. 211, 1875.

increase contemporaneously with increase of temperature;* whereas Heydenreich maintains that high temperature tends to destroy them—he having found that not only were they most numerous in the blood shortly before the fever was at its height, but that, also, outside of the body they would retain their movements longer in a room at 18° to 21° C. than at a higher temperature. He had been able to keep active spirilla in a preparation from a week to a fortnight at this temperature, whereas the spirilla died in from 15 to 21 hours when kept at blood heat (37°—38° C.). At 40°—41° C. they were found to perish still sooner,—namely, in from 4 to 12 hours.†

Although, as above shown, they can be preserved alive for a comparatively long time outside the body, nevertheless every attempt which has been made to "cultivate" them has proved abortive; no change has been observed to take place in them either in size or in number, notwithstanding that they have been "cultivated" in media of various kinds and at different temperatures.

E.—The relation of Microphytes to Disease.

In the preceding sections the leading facts regarding the connection of living organisms with the occurrence of disease have been detailed; it now remains to consider what grounds there are forbidding the adoption of the doctrine of a germ theory of disease;—why, for example, we should not at once admit that splenic disease is caused by bacteria-rods, and that the aim of treatment should be the destruction of the vitality of those rods; or that recurrent fever is caused by screw-bacteria, and such remedial measures resorted to as tend to destroy them.

Before such views can serve as the basis of anything like rational treatment it must be shown: (1) either that these organisms, as ordinarily met with, are injurious when introduced into the animal economy; or, (2) that the forms found in disease are in some respects morphologically different from those known to be innocuous,—such a difference, at least, as Virchow suggests, as exists between hemlock and parsley.‡

With regard to the first point, it has been shown over and over again that all the representatives of the group of fission-fungi can be introduced into the system with the greatest impunity. Not only is their complete innocuousness practically put to the test by every individual at every meal, but observations have been published which have conclusively demonstrated that they may be introduced directly, into the blood by injection into the veins, or indirectly, through the lymphatics in the subcutaneous tissue, without the slightest evil consequences. These facts are so well known and generally accepted that it is not necessary to refer to special observations.

With regard to the second question, however, diametrically opposite opinions are held,—all the advocates of the germ theory, with very few exceptions, maintaining that the particular organism, in the particular disease in which they are specially interested,

* Heydenreich's *Rückfallstyphus*, page 39.

† Loc. cit., pages 100, 101.

‡ "Die Fortschritte der Kriegsheilkunde, besonders im Gebiete der Infectionskrankheiten:" 1874, page 34.

is wholly distinct from all others; that is, if the organism happens to be anything more definite than a granule or molecule. The diseases which have been specially cited in the previous pages as being associated with microphytes may be divided, roughly, into two classes according to the form of the attendant microphyte—the septinous group, consisting of malignant pustule, septicæmia, and the malignant erysipelas or "typhoid" of the pig on the one hand; and a low form of fever commonly known as Typhus recurrent, Bilious remittent, Relapsing Fever, etc., on the other.

With reference to the organisms which have been found associated with the first-named group, taking Malignant Pustule as the type, it is to be observed that M. Robin,* in 1865, pronounced the bacteridia of Davaine to be identical with *Leptothrix buccalis*; and the well-known botanist, Hoffmann, has stated his opinion that they do not differ from like bodies which appear in milk and in meat solutions.† Ferdinand Cohn,‡ again, in his observations as to the growth of bodies of the same character in hay solutions, declares that the bacilli in the latter are identical in form and size with

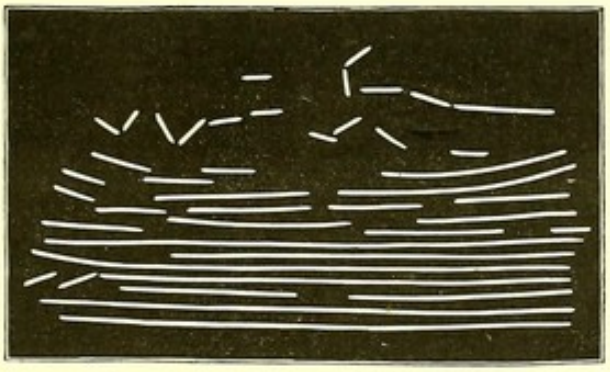


Fig. 49.—*Bacillus subtilis*: formed on the surface of a boiled infusion of hay which had stood 24 to 48 hours. (After Cohn.) × 650 diam.

those found in splenic disease, and that the various stages in their development correspond in every particular—the only difference which distinguished them being that, whereas *Bacillus anthracis* presented no movements, the bacillus of hay solutions did. This distinction, as has already been stated, has disappeared. Cohn's figure of the hay-bacillus is reproduced (Fig. 49), as it may, in the absence of the original paper, prove useful to such as would wish to get a clear conception of what *Bacillus anthracis* itself is like by examining so easily obtainable a substance as a little of the scum which forms on the surface of an infusion of hay.

F.—The Vegetable Organisms found in Healthy Blood after death considered in relation to the Bacteria and Bacilli of Diseases.

Several years ago Dr. Cunningham and myself were, whilst conducting various observations together, frequently struck with the rapidity with which organisms appeared

* *Traité du Microscope*, 1871, page 926.
† Birch-Hirschfeld, loc. cit., page, 206.
‡ Cohn's *Beiträge*, Band II, Heft 3, 1877.

in the blood and tissues of animals after death in this country [India]. These microphytes were not limited to minute spherical and elongated bacteria, but there were also present well-marked staves and filaments. In the report submitted by us in 1872, and again in 1874,* we drew attention to this matter and suggested the similarity between them and Davaine's bacteridia. A figure of these organisms, which were published by us at the time, is here reproduced (Fig. 50).

A short time ago a circumstance occurred which drew my attention again in a special manner to these organisms. Mr. Hart, a Veterinary Surgeon in Calcutta, forwarded to me for examination a little perfectly fresh blood which he had removed from a horse which had died that day of well-marked anthracoid disease. His curiosity had been aroused as to the microscopical characters of the blood by perusing an account, in the "Veterinary Journal," of "worms" having been found in the blood of horses suffering from a similar affection in the Punjab. A slide was prepared and examined under the microscope at once, but no marked peculiarity could be detected, but when

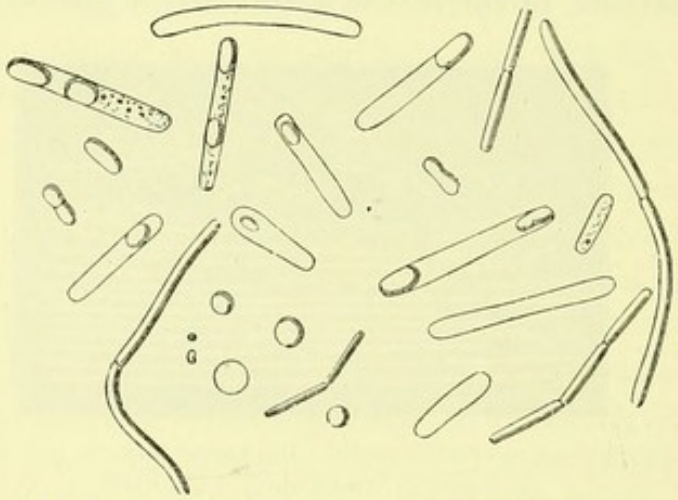


Fig. 50.—Organisms found in the tissues of *healthy* animals a few hours after death. × 1,500 diam.

this and other slides were re-examined twelve hours later, having in the meanwhile been kept under a bell-glass, numerous staves and filaments were observed, which, as to size and form, accurately corresponded with the description of like bodies characterising the blood in anthracoid diseases in Europe.

Several "cultivations" were started by adding a little of the blood to fresh aqueous humor. The preparations were then set aside for a few hours in a moist chamber. As the temperature of the atmosphere at that time was generally over 90° F., no special appliances were necessary for supplying artificial heat. The development of the rods into filaments and subsequent appearance of highly refractive oval bodies in the latter corresponded so completely with what Cohn, Koch, Ewart and others have described, that it is not necessary to give figures of the changes that took place. A series of such cultivations was conducted by transferring a little of the last cultivation to fresh aqueous humor, and so on from one preparation to another.

* Cholera: Microscopical and Physiological Researches, 1st and 2nd series, 1872 and 1874, reprinted at pp. 65 and 142 of this volume.

It was then determined to ascertain whether the bacilli found in the blood of animals which had been set aside for a few hours after death would manifest, under like conditions, similar changes during their growth. Rats were obtained, killed by means of chloroform, and set aside for from three to twenty-four hours, or longer, according as the temperature of the atmosphere was high or low. The result proved that, almost invariably, bacilli were to be found in their blood, in the spleen, and in other organs. On one occasion the rapid appearance of organisms after death was exemplified in a somewhat remarkable manner, and possibly the mode of death was not without some influence in determining their exceptionally early and plentiful appearance.

The man employed to procure the rats determined that he would get a sufficient number to last for some time, and proceeded to a large granary with his rat-traps. Having, however, found that he could procure more than could be accommodated in the cage which he had brought with him, he obtained a large earthen vessel, transferred twenty-seven rats into it, and tied a piece of cloth over the mouth of the vessel. As may be supposed, the rats had perished before he got home—all except one.

I examined the blood and the spleen of twenty of these rats within about six to eight hours of their having been caught, and found in each case that there were innumerable bacilli present, in every way morphologically identical with *Bacillus anthracis*. In some of the cases the number was astonishing. They were present chiefly in the form of rods, but here and there some were seen to have grown to such a length as to cover two fields of the microscope.

This experience tends to give support to the statement made by M. Signol before the French Academy to the effect that motionless bacilli, identical with those found in charbon, will be found in sixteen hours or less after death in the blood of animals which have been asphyxiated by means of a charcoal fire. M. Signol, moreover, found that eighty drops of this blood would kill a goat or a sheep very rapidly, notwithstanding that putridity could not be detected, so far as appearance and odour went; but that bacilli would not be found in the blood of the inoculated animals, either before or immediately after death.*

It has been urged that the microphytes which appear in the blood after death simply make their way into it from the intestinal canal as a result of the breaking down of the tissues. This objection is certainly no longer tenable, for many observers have shown that if some of the organs be removed from the body immediately after death, or indeed isolated from the circulation whilst the animal is still alive and under the influence of chloroform, these organisms will nevertheless appear if the preparation be kept for some hours at a suitable temperature.

Some of the specimens of blood which furnished several of the preparations about to be described were obtained in this manner. Rats, mice, kittens, etc., were placed under chloroform, and either killed and placed on one side for some hours; or, whilst

* *Comptes Rendus*, t. lxxxi, p. 1116, December 1875.

still under the influence of the chloroform, ligatures were passed around the several viscera so as to isolate them before death had taken place. Finally, a ligature was passed around the vessels at the base of the heart, and the organ severed from the body.

The specimens thus procured were repeatedly dipped into either melted paraffin or wax, by means of the string attached to them. In this way they became coated something after the manner of the cotton wick of a candle. Preparations thus made were set aside for from 12 to 24 hours according as the average temperature of the atmosphere was over or under 90° F., and it was almost invariably found that organisms appeared in them, almost, if not quite, as rapidly as they appeared in the bodies of animals which had been simply set aside under like conditions. In the former case, however, the supposition that they were derived from the alimentary canal after death is not possible; not can it well be maintained that they derived their germs from contact with the scalpel, string, etc., seeing that the entire surface was exposed to the influence of melting paraffin or wax.

The first figure in Plate XLI represents a tracing of a micro-photograph of the bacilli obtained in the manner above described from the blood of a mouse, to all appearances perfectly healthy when killed. A little of the blood was spread in a thin layer on a glass cover and allowed to dry, then, a drop of a solution of aniline-blue, was added to the slide, so as to stain the microphytes and thus render them more distinctly visible when focussed in the camera. The photographs were obtained by means of a $\frac{1}{16}$" object glass (immersion) made by Messrs. Powell and Lealand.

When first seen in the blood, the majority of these bacilli are motionless; in some preparations completely so, but in others they can be observed to manifest more or less distinctly marked, independent movements. They vary in size—in length chiefly, according as their development into filaments has advanced. The average length of each rod is found to be either 5μ or 10μ.* In the latter case a more or less distinctly marked bend will be recognisable, indicative of a joint. In more advanced stages of growth, two, three, or more such joints may be detected, especially on the addition of re-agents, such as tincture of iodine. In this case the bacilli will measure either 15, 20, 25, or more micro-millimeters. The length of these segments, whether attached or free, varies considerably in preparations from different animals, and even in preparations from the same animal; so that staves may be seen to range from 3 to 6μ in length, and occasionally even to exceed these limits. The average width of the staves was 1μ, but deviations from the average were equally evident in these measurements also. Sometimes it was found that the specimens present in one organ are smaller or larger than they are in another belonging to the same animal.

* μ = micro-millimeter (·001 mm.). This mode of stating the measurements is adopted in connection with this series of observations for convenience of comparison with like observations regarding Bacillus anthracis. It will be convenient to remember that the average size of a human red blood-corpuscle = 8μ.

If a very minute quantity of blood of this character be placed on a slide with a little aqueous humor, it will be found that in the course of four or five hours, if the temperature be about 90°, the bacilli will have grown very considerably, the majority measuring 20 to 60μ, and here and there in the preparation a filament may be observed stretching half across the field of the microscope. A few hours later still, a mesh-work of well-formed filaments will be manifest (Plate XLI, Fig. 2). Some of these filaments will be found to be distinctly segmented, others apparently without a single segment in their entire length, though even in these a tendency will be observed to form more or less acute angles at certain distances. Other specimens will be found to show traces of segmentation at either end or towards the middle. Drying the specimen, or treating it with re-agents, will make the segments much more distinct.

A few hours later some of the filaments will be seen to contain brightly refringent, long-oval molecules, varying slightly in size, but 1·2μ in length, by 1μ in width, may be given as fair average dimensions. These are the "spores" which have been described in *Bacillus anthracis*, etc. In a short time these refringent bodies dot the entire length of the filaments, a tendency being manifested to present groups of twos along the line. Gradually the filaments become more and more indistinct, until, finally, only the more or less distinctly linear arrangement of these refringent bodies remains to indicate the path of the filament (Plate XLI, Fig. 3).

I have spent many hours, days even, in watching isolated molecules of this kind, but have never been able to see anything which would warrant my saying positively that they germinated: I can only support what Nägeli, de Bary, and others have persistently affirmed, namely, that the Schizomycetes multiply by fission only. The bodies described and figured as germinating by Cohn, Koch, and others (Figs. 41, 42, page 574), may be seen in most preparations, some of which will be found figured by myself in Plate XLI, Fig. 5, but, so far as my experience goes, none of the objects delineated represent the germination of "spores" or conidia; certainly, here and there, bodies may be seen which at first sight appear very like it,—such, for example, as the refringent molecule figured at 5 *a*, as seen by Powell and Lealand's $\frac{1}{16}$th immersion, —but frequently the extremely translucent filament attached to it extends beyond the "spore" at either end (Fig. 5 *b*), thus showing that the filament is not formed of plasma which had proceeded out of the spore, but is, in reality, a tube enveloping it. It has been observed already that the observers who maintain that these refractive bodies germinate, base their opinions on different grounds. Their figures in most cases agree, but their interpretations differ.

It may be suggested that, although the bacilli found in the decomposing blood of healthy animals do produce spores, they are not of the same character as the spores found in *Bacillus anthracis*. To this it may be replied that Cohn states that the spores in the latter are identical in appearance and run through the same developmental stages as the spores of the *Bacillus subtilis* of hay-solutions, so that the remarks which I have ventured to make regarding the "spores" of the bacillus of ordinary blood

apply equally to bacillus of hay-infusions, for I have been unsuccessful in witnessing anything like the germination-process in the "spores" of the latter also. Nor were the "spores" which formed in bacilli associated with the anthracoid-blood of the horse, observed to germinate.

With regard to specific distinctions which have been based on the differences of size which microphytes of this character present—specific distinctions which, in all probability, will be still further advocated in the future—it is of interest to note that the bacilli found in the blood and tissues of animals which, at the period immediately preceding their death, had been perfectly healthy, manifest considerable latitude in this respect. The following extracts from my note-book may serve as illustrations of this, and, at the same time, furnish a brief epitome of the changes which bacilli-filaments undergo under very slightly varying circumstances. The first series of extracts will refer to bacilli of a smaller size than ordinarily seen. The notes run as follows:—"Killed two mice yesterday and examined one of them to-day, 24 hours after death. The red blood-cells from blood taken from the heart fairly well preserved. Numerous short bacilli present—motionless. The spleen also crowded with similar bacilli. They appear to be of a smaller size than are usually met with, the segments averaging only 2·5μ in length by ·8 to 1μ in breadth; though, in many of the rods, indications of segmentation could not be detected, or detected only in parts of them. The segments became more evident on drying, so that measurements could be accurately made. The sketch has been drawn accurately to scale (*vide* Plate XLI, Fig. 6). A drop of aqueous humor was placed on a cover-glass and a needle dipped into the spleen, and then applied to the droplet of humor. The cover was inverted and placed on a glass slide, hollowed in the centre, a little olive oil having been placed along the rim of the hollow to maintain the cover in its position. Another specimen was prepared and mounted on a slide in the ordinary way (*i.e.*, without access to air except along the edge of the cover-glass), and both were set aside until the following day."

The course taken by the latter preparation is described as follows: "The 'ordinary' preparation of yesterday's note was found to have altered somewhat. At one side of the slide a number of *bacterium termo* had developed, forming a whitish rim; along with these were staves of the same character as described yesterday, but considerably grown, which were being knocked about in all directions by the bacteria. The greater portion of the preparation had gone on to 'spore' formation, as figured at *a*, Plate XLI, Fig. 7. In others the filaments and joints were still distinct and presented a protoplasmic aspect (*b*). Many of the filaments were held together by very slender cords, sometimes as if by one corner only, probably owing to a twisting of the tube; at others the continuation of the tube was distinct (*c*). [Compare this description with the figures of *bacillus anthracis* reproduced from Dr. Cossar Ewart's paper, Figs. 43 and 44, page 575.] Here and there filaments could be seen in a transition stage, a 'spore' having

formed in each segment, the joint being still faintly visible, but the plasma disappeared except at one or two parts—generally the end-segments of a thread (*d*). Commonly the separated segments contained two 'spores,' presumably coinciding with the original number of segments. The threads are wider when containing 'spores' than previously. The 'spores' = 1 to 1·4μ in length, by ·8 to 1μ in breadth. The space allotted to each 'spore' in a filament, presumably each segment, was from 6 to 7μ in length, so that a filament containing two 'spores' would = 12 to 14μ, and three 'spores' = 18 to 21μ, and so on, so that the filament manifestly swells out in all directions."

The third day; "Having set the slide in moist air under a bell-glass, evaporation was prevented. Not much change has taken place, except that here and there it is seen that some of the 'spores' within the filaments present a longer appearance, and have become correspondingly narrower. In some a constriction is seen, and others are completely divided and form two minute molecules (Plate XLI, Fig. 8). In some instances the molecules had become separated. [Compare with Dr. Ewart's figure of *bacillus anthracis*, Fig. 44, page 575.] That the refringent particles were in reality the 'spores' of the previously distinctly seen filaments was evident from the circumstance that, although the hyaline tube which contained them was extremely translucent and only with difficulty brought into view, still it was sufficiently strong to be able to retain these refractive molecules in a row; any movement communicated to one part of the row was seen to be accompanied by movement of the entire series. The movements were caused by the constant agitation of objects in the field on account of the presence of *bacterium termo*."

No further change could be detected in the "spores."

The foregoing description, though applying to the more generally observed appearances which bacillus growths present, is by no means the only course taken by such organisms when transferred to nutritive media other than that in which they were developed, nor is it by any means a matter of certainty, at starting, what particular course will be followed by them. In illustration of this and also of the fact that, occasionally, exceptionally large bacilli are to be found predominating in the blood (just as we have seen to be the case with regard to exceptionally small ones), the following extract from my note-book may be instructive:—"A rat which had been killed at ten o'clock in the morning was dissected at five in the afternoon of the same day. The temperature had been about 94° F. The heart was carefully taken out and a minute quantity of blood transferred, on the tip of a scalpel, to a slide. A small quantity of a half per cent. solution of salt and distilled water was added, in order to dilute the preparation, and, by separating the corpuscles, render it easy to see any foreign matters that might exist in the serum. There were numerous motionless bacilli varying from 4 to 20μ in length, by ·8 to 1·4μ in width, the thicker variety predominating (Plate XLI, Fig. 9). The majority consisted of short stiff rods, 5·5μ in length, or double this length; in the latter case often manifesting indications of a tendency to bend towards the centre. There were also a few thicker rods than these

scattered throughout the preparation. An hour having been spent in the examination of this slide, it became apparent that the bacilli were more numerous on it than when the examination commenced. It was then set aside in a moist chamber.

A similar slide was prepared consisting of just a trace of the blood mixed with fresh aqueous humor, and placed in the same chamber.

On the following morning this slide, to which the half per cent. salt solution had been added, was re-examined, and it was found that the filaments had grown greatly in length and somewhat in thickness (Plate XLI, Fig. 10); in some instances the filaments extended across the field of the microscope. All the filaments were motionless and almost translucent, quite devoid of granularity, and it was only in some places that a joint could be distinguished. No refringent molecule appeared in any of these long filaments, but there were some short, pale, transparent rods rolling about in the preparation, and in these glistening bodies were found (Plate XLI, Fig. 12). Some of these rods, or segments, were 8μ long, and contained a bright blue (as seen with Hartnack's No. 9 immersion objective) "spore," 2μ in length by 1μ in width, and other segments, about the same length, contained two. Mixed with these were short, translucent staves, with a distinct joint, some with two "spores," separated by a partition, and others shorter ($4{\cdot}5\mu$) with only one. By the next day the filaments were broken down and the preparation consisted chiefly of a multitude of active *Bacterium termo*.

The other slide, which had been prepared with aqueous humor, was likewise examined on the following day. The filaments were not so long as in the other preparation, and there appeared to be a decided tendency towards cleavage into small cuboid pellets of plasma (Plate XLI, Fig. 11, *a*). Some of the filaments, though well preserved at one end, were seen to be undergoing the process of fission at the other, each fragment being equal to $1—1{\cdot}2\mu$ in its longest diameter. It seemed as if the 4 to 5μ-segments, of which the filaments were composed, had first become freed from the thread, and had, instead of giving rise to a "spore," undergone fission (Fig. 11, *b*). In other cases cleavage of this kind took place whilst the individual segments maintained their linear arrangement (Fig. 11, *c*). In some instances it seemed as if the two first halves of the originally 4 to 5μ-segments had each become elongated (and correspondingly thinner) and undergone further division, thus forming four more or less spherical plastides (Fig. 11, *d*). When the whole filament had undergone such a process and the plastides had retained their linear arrangement, it presented the appearance of a rosary chain (Fig. 11, *e*). It was ascertained that four of the plastides forming a part of the particular chain sketched were equal to the length of one of the segments of the original filament, *viz.*, 5μ.

It will thus be seen that filaments of bacilli may disappear, at least, in two ways: (1) by giving rise to minute highly refractive, long-oval molecules, the filaments themselves becoming at first transparent, and then, apparently, disappearing more or less completely; and (2) by undergoing cleavage, and giving rise to minute plastides. These may, occasionally, be observed to present a rosary-chain arrangement, but usually their

identification becomes impossible owing to their mixing with other molecules in the field.

I am not in a position to offer any suggestion as to which is the normal course for bacilli to take, seeing that bacillus-filaments may re-develop under suitable conditions from material derived from preparations in which either of the two foregoing processes has been observed to take place. Probably, to a greater or less extent, both processes occur together; at least it is seldom that filaments will give rise to the bright, refractive molecules, in a highly nutritious fluid, without a contemporaneous formation of plastides taking place at some part of the preparation.

G.—The relation of the Spirillum of Recurrent Fever to other known Spirilla.

Having thus endeavoured to prove that no sufficient grounds have been adduced for accepting the doctrine that bacilli have been found in splenic disease, septicæmia and

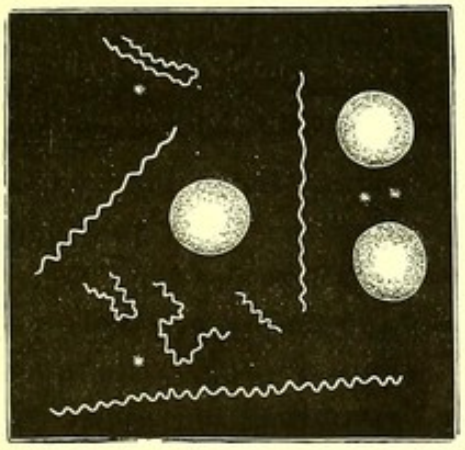


Fig. 51 . . . . × 600 diam.
Spirillum (*Spirochæte*) *Obermeieri*. The spirilla among blood-cells * * in active movement. Those marked * sketched a short time before the cessation of the fever. (After Weigert; published by Cohn.)

Fig. 52 . . × 650 diam.
Spirillum (*Spirochæte*) *plicatile*.
(After Cohn.)

so forth, which differ, not only in any *material* respects, but in any respects whatsoever, from bacilli which may be found under certain easily induced conditions, it remains to be seen what evidence there exists to show that the other member of the schizomycetes group found in recurrent fever—*Spirillum Obermeieri* (Fig. 51)—differs from other spirilla known to be harmless.

On this point also considerable diversity of opinion exists, though perhaps not quite to so marked an extent as with respect to the microphytes which have just been considered. The matter is, moreover, made somewhat simpler from the circumstance that those who have had the greatest opportunities for personal observation are, on the whole, the observers least inclined to claim for this spirillum specific character in the ordinary botanical sense of the term.

Since the period of its discovery in the blood by Obermeier it has been referred to under various names: *Spirothrix*, *Protomycetum recurrentis*, in Lebert's article on

recurrent fever and in Ziemssen's "Handbuch" of Medicine; *Spirillum* by Erichsen, Litten, Birch-Hirschfeld, etc.; *Spirillum tenue* by Naunyn; and *Spirochæte Obermeieri* by Cohn (Fig. 51).

The last-named observer, and the only one with an extended botanical experience, gave it a specific distinction solely on physiological grounds, as, after careful examination, he was unable *to detect any difference, either of size or in character of movements*, between the spirillum of recurrent fever-blood and *Spirillum* (*Spirochæte*) *plicatile*, which had been found by Ehrenberg in water many years ago.* Cohn himself had subsequently found it in water, and *also* in the mouth—in the mucous surrounding the teeth.† A figure of this spirillum by Cohn is reproduced for convenience of comparison ‡ (Fig. 52).

It will be recollected that the late Dr. Obermeier himself had recognised the spirillum in the mucous from the mouth of recurrent fever patients, possibly having overlooked the circumstance that its presence in this fluid was not an abnormality. Manasseïn,§ who, at St. Petersburg, has had favourable opportunities for observation, expresses himself most strongly against the supposition that this microphyte is anything more than an epi-phenomenon in recurrent fever. Not only was it absent from the blood in certain of the cases of fever examined by himself and others, but spirilla precisely similar to those found in other cases were, during a period of some months, constantly present in the secretion which flowed on pressure from an abscess which opened into the mouth of a fever-free patient. Billroth also states that similar spirilla were found in connection with caries of bone.

Heydenreich, who probably has investigated this matter as carefully as any observer, and written the fullest account of it which has come under my notice, notwithstanding his manifest desire to claim for the spirillum a causative relation to the disease, is, nevertheless, compelled to own that sufficient reason has not been shown to warrant its being described as specifically different from the spirillum of water and the ordinary spirillum of the mouth.‖

In May 1877 I had an opportunity of observing cases of fever in Bombay in which Dr. Vandyke Carter had demonstrated the existence of spirillar organisms in the blood. Dr. Carter has recently published an interesting account of his observations.¶ These, as far as the abstract of the paper submitted to the Pathological Society shows, coincide closely with like observations in Europe. During my stay in Bombay I had an opportunity of examining twenty-five cases of the disease, and observed the spirillum in five of these

* Cohn's *Beitrage;* Band I, Heft 3, 1875, p. 197.

† Ditto, Band I, Heft 2, 1872, p. 180.

‡ Ehrenberg suggested that the term *Spirillum* should be restricted to such of the Schizomycetes as manifested spiral movements without flexibility, and for those of the group which were distinctly flexible he proposed the term *Spirochæte*. As, however, the distinction is merely a matter of degree, spirilla also manifesting a greater or less amount of flexibility, I have adhered to Dujardin's classification. Fomental (*Etude sur les Microzoaires*, 1874) adopts the older and simpler term for a like reason.

§ *St. Petersburg. medicin. Wochenschrift.* No. 18, 1876.

‖ Op. cit., page 31.

¶ *The Lancet*, June 1878.

on several occasions. It could not, however, be said that the other subjective symptoms in these cases were more grave than in other cases of the fever, in which not a trace of the spirilla could be found.

One of the preparations of blood, containing these organisms, which I was able to preserve, is a particularly good one, and as it was obtained by exposing the fluid immediately on its removal to the fumes of a weak solution of osmic acid, it may be considered as representing the spirilla exactly as they appeared in a perfectly fresh slide. The fumes of this acid, as has been stated by several observers, are particularly useful in preserving the natural appearance of these microphytes, as, indeed, of blood-preparations generally. Professor Ray Lankester, when recommending its use to English observers, wrote: "It is sufficient to expose a thin film of blood on a glass cover to the vapour arising from a bottle containing a 2 per cent. solution of osmic acid, during three minutes, to

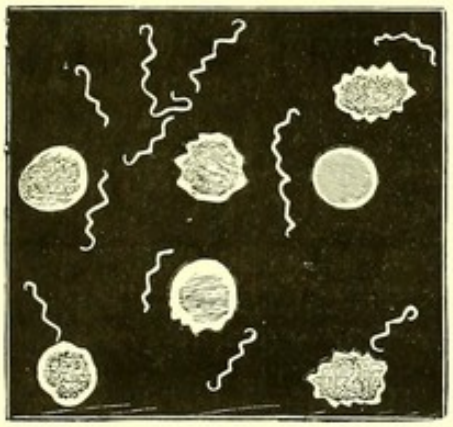


Fig. 53 . . . . × 700 diam.

Spirilla in the blood of fever-patients in Bombay: Traced from micro-photographs taken with Ross's $\frac{1}{12}$" immersion objective. Some of the longer spirilla in the wood-cut are in the micro-photographs seen to consist of two fibrils loosely attached at the ends. This peculiarity cannot be reproduced in the engraving. Several of the blood corpuscles present a stellate appearance.

ensure its complete preservation. Every corpuscle thus becomes 'set,' as it were, in its living form; there is no coagulation, no shrinking, no dissolution; but as the corpuscle was at the moment of exposure to the vapour, so it remains. The white corpuscles even exhibit their pseudopodial processes arrested in the act of movement. It is as though the osmic acid bottle contained a Gorgon's head, which freezes the corpuscles, as they face it, into stone.*

I have prepared several micro-photographs of this slide in the hope of being able to supply facsimile copies of some of them with this paper. I fear, however, that it will not be practicable to obtain reproductions of the negatives by any of the permanent photographic processes practised in Europe in sufficient time to permit of their publication at present. I have therefore caused tracings of some of the leading forms to be made and have had them engraved on wood † (Fig 53).

* Quarterly Journal of Microscopic Science, vol. xi, p. 370, 1871.

† Two of these micro-photographs will be found reproduced in Plate XLIII.

In the last number of Cohn's *Beitrage* (Band II, Heft 3), Dr. Koch has supplied some excellent permanent micro-photographs of the spirilla as observed at St. Petersburg. The spirilla in the osmic acid-preparation which I possess, though presenting the same general characters as those in Dr. Koch's photographs, are somewhat thicker than those depicted in the latter; whether this points to any slight difference in the blood between the fever which prevailed in Bombay last year and the fever which prevailed in St. Petersburg I am not prepared to say, but this much, I think, I may venture to state, namely, that the difference between the spirilla in the preparation in my possession, and those received from St. Petersburg, as photographed by Dr. Koch, or the spirilla sketched by Weigert (Fig. 51), is as great as the difference which exists between the *Spirillum Obermeieri* and the *Spirillum plicatile* on the one hand, and the *Spirillum* of the mouth on the other. As has already been seen, these differences are exceedingly trivial, and it is quite possible that such slight differences may exist in these microphytes in different persons during the same epidemic, and at different times in the same individual, as has been shown to be the case in the preceding pages with regard to the bacilli in the blood.

It may be useful to say a few words, in passing, regarding the fever which was so prevalent in Bombay during a great part of 1877, as some misapprehension appears to exist as to its exact character. What is described as recurrent fever, and sometimes as bilious typhus or bilious remittent fever, and recurrent typhus, in Germany, is frequently assumed in England to be the same as the "relapsing-famine fever," which was witnessed some years ago in Ireland and elsewhere. Whether in reality the latter fever was or was not the direct offspring of want is not a matter calling for comment here, but what is very definitely known is that outbreaks of recurrent fever in various parts of Russia and Germany, and which were found to be associated with spirilla in the blood, have occurred in districts wholly unassociated with want of any kind. In some cases, indeed, the outbreaks occurred in districts and during periods in which the labouring classes were exceptionally well off. This is a point concerning which no doubt whatever can exist. With regard to the supposed connection of the fever in Bombay with the famine which prevailed in certain parts of the country, I can only state that, so far as I could gather as the result of personal observation and careful inquiry, no sufficient grounds existed to warrant any such supposition; and Surgeon-General Hunter, after a most careful analysis of the official records, and writing from personal acquaintance with the disease, thus sums up his report on this particular point: "Any distinct causal connection, therefore, between the famine and the fever must be abandoned."*

It thus follows that the term "relapsing-famine fever" is not applicable to the affection hitherto associated with spirilla in the blood, whether in Germany, Russia, or Bombay.

* *Indian Medical Gazette*, October 1st, 1877.

H.—The probabilities in favour of the Bacilli and Spirilla of the Blood being Epiphenomena.

There is one circumstance in connection with the microscopic appearance which these organisms sometimes present which deserves special mention, as it may serve as an explanation of their sudden disappearance from the blood; and that is that they may present a well-marked beaded or rosary-chain appearance (Fig. 54). This feature I was able to observe on one occasion only. The spirilla of the ordinary character were plentiful in this person's blood on the evening previous to the day on which this observation was made, but when examined on the following morning there were only linked or rosary-chain spirilla in his blood. They were not very numerous and their movements were not of that *rushing* character ordinarily observed, but conveyed the impression of *tumbling* across the field.

The inference which such an observation appears to warrant is, that when the blood acquires a certain as yet undetermined condition it becomes unadapted to the existence of spirilla, and that the fibrils thereupon undergo segmentation, after the manner of other schizomycetes [compare with Fig. 11, Plate XLI], and the separated plastides become diffused throughout the circulation; possibly they then gradually disappear in the same manner as we have seen other plastides (minute bacteria, etc.) disappear very rapidly after being injected into the circulation. This appears to me to be more probable than that they continue in the circulation until the blood re-acquires the state suitable to their growth into fibrils, seeing that the time for their return is so uncertain—it may be two days, may be six days or a fortnight even, and perhaps they may not return at all. Be that as it may, it is clearly evident that their existence as spirilla is dependent on the composition of the fluids of the body.

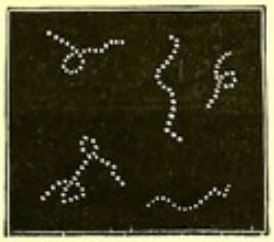


Fig. 54.—Beaded or rosary-chain appearance assumed by the spirilla found in the blood of a fever patient at Bombay (sketched as seen by Hartnack's immersion objective No. 9, ocular 4).

Heydenreich suggests that their disappearance is due to the elevated temperature of the blood at the height of a paroxysm. If that were the case, they ought to become more numerous with the fall of temperature after death, but it is well known that they disappear exceedingly rapidly when life becomes extinct, in this respect offering a marked contrast to other members of the cleft-fungi group—bacteria and bacilli.

The fact of their total disappearance immediately after death, or probably even before death actually takes place, is very significant as showing the extremely close relation which exists between them and the blood in *living* tissues, seeing that when the blood is removed from the body the spirilla will, under favourable conditions, retain their power of locomotion for several hours or days. What these subtle changes of the blood during fever-processes may be, chemistry and physiology have not yet revealed; we can therefore only judge of them by the changes of the temperature,

etc., of the patient; and, in the particular condition under consideration by the occasional appearance and re-appearance of spirilla, whose presence is manifestly dependent on antecedent changes. That the temperature commences to rise and that other subjective symptoms are manifested before the appearance of spirilla, testifies to this, for it cannot be that they can exert an influence before they are themselves existent.

Dr. Charles Murchison, at the discussion on the germ-theory of disease at the Pathological Society,* put this matter very clearly when he said, "The fact that in relapsing fever and sheep-pox distinct forms of bacteria have been found in no way proves any causal relationship between these diseases and the bacteria, and is readily accounted for by the acknowledged fact that the form taken by many minute growths depends not upon the germ, but upon the nature of the medium in which it grows. Indeed, the observations which have been made on the spirilla of relapsing fever are strongly in favour of this view, for they are present in the blood during the first paroxysm, but disappear before the crisis; are absent during the intermission, but return with the relapse of fever, and again disappear before the crisis. It seems difficult to account for their appearance and annihilation twice over, except on the supposition that the soil was suitable for their development during the febrile process, and unsuitable when the febrile process was complete." The remarks which Dr. Bastian made in opening the same discussion on his very interesting observation as to the presence of bacteria in the fluid of a blister-bleb of a febrile patient so long as the bleb remained intact for forty-eight hours, whereas in the fluid of a blister from a healthy person no such appearances would be seen, point in the same direction.

A like conclusion must be arrived at regarding the bacilli in malignant pustule, septicæmia, and the so called "typhoid fever" in the pig, horse, and other animals. With regard to the microphytes, just named, it may be confidently stated that they are never to be detected in the earlier stages of the disease, but only at a brief period before and after a fatal termination. To my knowledge they have never been found in the blood of animals which have subsequently recovered; they have always been recognised only as one of the concomitants of impending dissolution. This is undoubtedly the case so far as the two diseases first cited are concerned, and judging from what is known regarding them, I presume that the development of such organisms in the blood of the inoculated pigs was not one of the symptoms which Dr. Klein had observed as indicative that the bacilli which had been introduced into the system of the animals had induced the disease. Should this inference prove to be correct, it is somewhat difficult to understand on what grounds so emphatic an opinion could have been expressed as to their specific action. It does not appear that Leisering in his account of like organisms, in apparently the same disease of the pig (as already mentioned), had found them in any but fatal cases.

* *The Lancet* and *British Medical Journal*, April 1875.

I.—The evidence which has been adduced showing that the virulence of Septinous Substances is not dependent on vegetable life.

Seeing that so much evidence can be adduced to show that these organisms, whether bacilli or spirilla, are but epi-phenomena, *the specific change in the fluids of the body having taken place before the slightest indication of their presence can be detected*, the question which naturally suggests itself is: whether sufficient evidence exists to show that inoculations can be effected with like material in the absence of such living organisms. The reply to this question, so far as anthracoid and cognate diseases are concerned, is distinctly in the affirmative; but, with regard to recurrent fever, it cannot be as yet definitely stated that the malady is inoculable, so that for the present it may be left out of consideration.

When Brauell published his paper in Virchow's *Archiv* in 1858 detailing his experiments to prove that splenic-fever was an inoculable disease, he further stated the opinion that the organisms found in the blood could not be the carriers of the virus, seeing that blood not containing bacilli had been found to generate the disease. Bouley has arrived at a similar conclusion, and Bollinger, who has repeated Brauell's and Bouley's experiments, has also shown that the disease may exist without the presence of bacilli in the blood, that such blood will induce the disease in other animals, and that even under such circumstances organisms may develop in the blood of the inoculated animal, and be detected during life, as well as after death.*

Similar observations have been made with regard to septicæmia, and the allied disease-conditions associated with the presence of bacilli, some of which have been already referred to. M. Colin, for example, found that $\frac{1}{100000}$ of a drop of septicæmia-blood would kill a rabbit in 36 hours when inoculated by means of a lancet; that the virulent property existed before the appearance of rod-bacteria; and that the pernicious character of the fluid became evident contemporaneously with the advent of very minute spherical bodies, the consequences, as Colin believes, of the altered character of the blood.†

It has been repeatedly demonstrated that the poisonous properties of septinous blood and of other decomposing animal solutions gradually disappear towards the third or fourth day, a fact which is scarcely reconcilable with the doctrine that the poison resides in the apparently almost imperishable "spores" of the bacilli which existed during the earlier stages of decomposition. A like feature characterises the virus of splenic disease, of small-pox, and of syphilis. Hiller,‡ in summarising the results of filtration of septinous fluids, writes that the most decisive experiments have demonstrated that after filtration through finely porous material, such as charcoal, porous earthenware, compressed wadding, etc., until the fluids have been shown to be absolutely free from

* O. Bollinger: "Zur pathologie des Milzbrandes:" München, 1872. Quoted in Schmidt's *Jahrbücher*, Bd. 166, p. 205; 1875.

† "Nouvelles recherches sur l'action des matières putrides et sur la septicémie." *Bulletin de l'Académie*, October 1873; cited by Birch-Hirschfeld, l. c., page 174.

‡ "Ueber putrides Gift," *Centralblatt für Chirurgie*, Nos. 10, 11, and 12, 1876.

visible molecules of every description, they are, nevertheless, still competent to induce all the symptoms which characterised their action before such filtration. These results, Hiller says, were arrived at by Panum, Bergmann, Weidenbaum, Wolff, Küssner, and others.

To the first named of these observers belongs the merit of having contributed some of the earliest and most valuable observations which have been, hitherto, recorded in connection with the nature of the poison existing in certain solutions of decomposing animal matter. Panum's researches were published so far back as 1855, but having originally appeared in Danish they had for several years been to a great extent overlooked. They were brought more prominently into notice on their publication in 1874 in Virchow's *Archiv*. In 1875 * Dr. Cunningham and myself drew attention to these experiments, as we had found that the results of observations made by us, with a like object, based on a series of experiments which included the inoculation and dissection of about 170 dogs, were, in so far as they were comparable, almost in complete accord with those which had been obtained by this distinguished experimentalist.

Panum found that the coagulum produced by boiling a septinous fluid was more virulent than the fluid itself. The principal facts demonstrated by him may be thus summarised:—

(1)—That the perfectly clear fluid which may be obtained by filtering solutions of putrefying animal substances through several layers of filtering paper would induce the characteristic symptoms of the same kind as the unfiltered material.

(2)—That boiling such a fluid for even 11 hours would not materially impair its toxic properties.

(3)—That although an alcoholic extract of such a fluid proved to be inert, the virulent action of a watery extract of the same fluid was very intense.

Panum therefore concludes that a fluid which can retain its specific property after being filtered, boiled, evaporated to dryness, and the residue digested in cold and in boiling alcohol, then re-dissolved and again filtered, cannot owe this property to living organisms of any kind.

In 1865 Dr. B. W. Richardson showed that the sero-sanguineous fluid from the peritoneal cavity of a person suffering from pyæmia would communicate fatal disease from one animal to another in a direct series, and that the poison (designated "septine") which effected this could be made to combine with acids so as to form salts which retained the poisonous qualities of the original substance.† A few years later (1868), Bergmann succeeded in obtaining apparently a similar sub-

* "Cholera: Microscopical and Physiological Researches," Series II., p. 142 of this vol.

† *The Lancet*, April 3rd, 1875, p. 490.

stance and named it *Sepsin.** This poison induced symptoms of a like character to what are induced by putrefying solutions, and was frequently even more fatal, in very small doses. Still it appears not to reproduce symptoms exactly similar to the original material, in this respect differing slightly from Panum's "putrid extract," which reproduces the ordinary symptoms of septic poisoning without any modification whatever.

To Pasteur and his adherents, who ascribe what may be almost termed supernatural powers of resistance to the "resting spores" of anthracoid and other diseases, the facts adduced in the foregoing paragraphs can carry but little weight. But another series of phenomena have been recorded which point in the same direction. It has been shown that the living tissues of the body will under certain conditions, when irritated by means of purely chemical irritants,—such, for example, as a strong solution of iodine or liquor ammonia,—secrete a fluid which, when transferred from animal to animal, proves not one whit less virulent in its properties than an exudation which has resulted primarily from the introduction into the system of material which has swarmed with bacilli. Observations to this effect have been published by many observers, and Dr. Cunningham and myself have placed on record that we found a large number of bacteria in the blood of a dog which had died as a result of such chemical irritants. These bacteria could not have been the cause of death, nor, most assuredly, could they have derived their origin from the liquid ammonia which had been resorted to to excite the inflammatory process.

It would seem from these results that the living tissue elements of the body itself play a much more important part in the elaboration of septinous and allied poisons, than what has been of late ordinarily ascribed to them.

Such, so far as I have been able to learn, are the main facts which have been recorded with regard to the microphytes of the blood in health, and in diseased conditions.

II. THE PROTOZOA WHICH HAVE BEEN FOUND IN THE BLOOD.

THE organisms which have been described in the former part of this paper, as is well known, were, until within the last few years, considered to be more allied to animals than plants, and were consequently classified as belonging to the animal kingdom. Häckel even now places them in his intermediate kingdom, the *protista;* and for a considerable time subsequent to the promulgation of the doctrine of fermentation by the agency of living cells, vibrionic fermentation, of various kinds, was supposed to be effected by animal life—the animalculæ, during the respiratory process, depriving the solutions in which they were found of the oxygen which they contained, and thus starting a series of complicated changes. It has, however, been for some time con-

* *Centralbl. f. d. medicin. Wissensch.*, 1868, p. 497 ; cited by Dr. Arnold Hiller, op. cit.

ceded that the schizomycetes are more akin to plants than to animals, and the advocates of the vital theory of fermentation have adopted this view and demonstrated to very general satisfaction that a like explanation still suffices to account for initiating the changes in question. So far as I am aware, the view is no longer held that animalcules are competent to start fermentative processes, notwithstanding the circumstance that microzoa, tolerably high in the scale of beings, are very ordinary accompaniments of microphytes in solutions undergoing active changes of this character. They are not, however, such constant accompaniments as fungi, nor are they recognised so early in solutions of this nature—a more or less distinctly marked interval being observed between the occurrence of manifest chemical change in them and the appearance of protozoa. With regard to protophytes, however, very often no such interval can be clearly demonstrated, and it has been consequently concluded that no such interval occurs—that fermentation of suitable fluids and the advent of fungi are essentially synchronous.

A.—Flagellated Organisms in the Blood of healthy Rats.

It will be recollected that in a former chapter one of the fundamental tenets of M. Pasteur's creed was cited,—namely, that neither microscopic organisms nor their germs were ever found in the blood of an animal in health. Doubtless our conception of what implies good health may differ, and especially so when it is the health of an animal, and not of a person, that may be the subject of debate. If it be maintained that an animal affected with either epiphytes or entophytes, with epizoa or entozoa, is not in the enjoyment of full health, then there can be but few perfectly healthy animals. The organs of some animals are almost never absolutely free from parasites. It would nevertheless be scarcely justifiable to pronounce such animals as diseased in the ordinary sense.

So much being admitted, it is scarcely possible that this portion of M. Pasteur's doctrine can be correct. For some years past I have taken considerable interest in this matter, and my attention was drawn to it in a special manner in May last year, by my having been directed by the Government to make inquiries regarding the spirillum of Bombay-fever, already referred to. Whilst doing this I had occasion to examine the blood of a considerable number of animals, and eventually (July 1877) detected organisms in the blood of a rat which, at first sight, I took to be of the nature either of vibrions or spirilla. The blood when transferred to the microscope appeared to quiver with life, but for some considerable time nothing could be detected to account for this animated condition, as the blood corpuscles were somewhat closely packed. On diluting the blood with a half per cent. solution of salt, motile filaments could be seen rushing through the serum, and tossing the blood corpuscles about in all directions. Their movements were of a more undulatory character than are the movements of spirilla, and the filaments were thicker, more of a vibrionic aspect. They were pale, translucent beings, without any trace of visible structure or granularity; but, as their

movements were so rapid, exact information as to their microscopical characters could not be ascertained at the time. The slides were therefore placed under a bell-glass until these should diminish.

On the following morning the activity of the filaments was much less. Their movements were more restricted and more undulatory in character, and the blood-corpuscles, having become somewhat agglutinated, had apparently squeezed out the organisms, so that the latter occupied the serum-areas of the preparations. After watching their movements for some time under a Hartnack's No. 9 immersion objective, it was observed that every now and then blood-corpuscles, some considerable distance from any visible motile filament, would suddenly quiver. On carefully arranging the light, it was eventually observed that this movement was due to the existence of a very long and exceedingly fine flagellum, apparently a posterior flagellum, as the organisms seemed generally to move with the thicker end forwards—the flagellum being seen following it, and lashing the fluid during the moment it remained in focus. I have

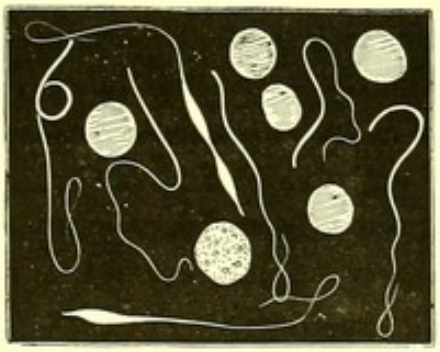


Fig. 55 . . . . × 700 diameters.

Flagellated organisms in the blood of healthy rats. A few red blood-corpuscles and one white corpuscle are included in the figure.

not been able to detect any flagellum at the opposite end. The greater number of the figures reproduced in the woodcut (Fig. 55) represent these organisms as they are observed a few hours after the blood has been obtained, when their movements are not so rapid and the flagellum becomes recognisable. They may sometimes be kept alive for two or three days, but generally the greater portion will have died within twelve or twenty-four hours; and not only have died, but also disappeared from view.

When very carefully watched, the plasma constituting the thicker portion of their substance may be seen suddenly to swell out at certain places—sometimes so as to divide the "body" into two parts, as shown in the middle figure; at other times two or three such constrictions and dilatations may be detected, the dilatations being possibly observable only on one side. At other times they assume an arrow-shaped aspect, as shown in the lowest figure. Occasionally something like granularity may be observed before their disappearance, but not a trace of them is left after their disintegration: it seems as though they had been dissolved in the serum in which they were found.

They may readily be preserved by spreading out a thin layer of the blood containing them over a thin covering glass and inverting it over a weak solution of osmic acid. The preparation should be removed as soon as it presents a dry, glazed appearance, and may be thus mounted in the dried condition or in a saturated solution of acetate of potash. I have, however, never been able to detect the flagellum in such a preparation; apparently the refractive index of the substance forming the flagellum and that of the serum approximates so closely that the last can only be detected when creating a current by its movements. The "body" remains nearly as translucent after the action of the osmic acid-fumes as it was in the living condition, so that the presence of the protozoa in such a preparation may readily be overlooked owing to the absence of any movements to direct attention to them.

When, however, a preparation of blood of this kind is dried in the manner ordinarily suggested for preserving specimens of blood, and especially if a little of a weak solution of aniline-blue be afterwards poured over the dried slide, the body of the protozoon will present a very different appearance. It will be found to have contracted irregularly, and to manifest a somewhat granular and *shreddy* appearance, suggestive of a coagulated, fibro-albuminous substance. The "body" portion becomes flattened towards its middle to double its original width, and both ends become almost acutely pointed. The flagellum part is only visible for about half its true length, and this portion of it appears to consist of the same substance as the body. Possibly the now invisible portion of the flagellum may consist of a substance slightly different from that of the body; or may have been retracted during the drying. I have made micro-photographs of slides prepared in both ways, hoping that possibly an image of the entire lash might thus be obtained, even though the eye could not distinguish any, but have not succeeded, notwithstanding that the rays of light were caused to pass through glass of various colours.* The logwood solution recommended by Koch for this purpose also failed in my hands.

It is impossible to secure accurate measurements of these organisms during the period of activity, nor of the lash at any time, seeing that the latter becomes for the most part invisible in preserved preparations. The body portion, however, may readily be measured after they have been killed by means of osmic acid. The width of the anterior half, or body portion, averages ·8 to 1μ, or precisely that of ordinary blood-bacilli, and its length from 20 to 30μ, or an average of 25μ. The flagellum, so much of it as is visible, is somewhat of the same length, so that the total length of the organism equals about 50μ, or about $\frac{1}{500}''$. The lash, however, may be considerably longer than this, as the slope from the body portion is very gradual, and when the eye follows it to the bounds of visibility an impression is conveyed that there may be still more of it, beyond the power of either Ross's $\frac{1}{12}''$ or Powell and Lealand's $\frac{1}{18}''$ to reveal.

They are not very sensitive to the action of re-agents; a weak solution of

* Facsimiles of two of these micro-photographs will be found in Plate XLIII.

ammonia did not affect them for some time, but a stronger solution of potash affected such of them as it came into contact with at once: others in the middle of the field continued to exhibit movements for several hours; probably they had not been touched by the potash. A weak solution of bichloride of mercury in acetate of potash and camphor water (as used for preserving preparations) did not seem to affect them materially, seeing that they maintained their activity in such a solution for eight hours. They retain their vitality longer in a weak salt-solution than in pure distilled water. A cover-glass with an aqueous solution containing them was inverted over a bottle of chloroform for several minutes, but the movements of the organisms were unaffected; if, however, a drop of blood containing them be similarly placed over chloroform they disappear, probably owing to the action of the chloroform-vapour on the blood itself.

A drop of the blood was placed on a slide arranged for the application of electricity to microscopic preparations, and it was found that an interrupted current of such a strength as could not be comfortably borne by an individual was tolerated by these beings for several consecutive hours. The only difference appreciable between a preparation thus dealt with and one not so treated was, that the movements ceased a few hours sooner in the former than in the latter, possibly owing to the chemical change induced in the blood itself by the current.

I have examined the blood of a great number of rats for the purpose of ascertaining what proportion of them contains these organisms in their blood, and find that of those specially examined for this purpose their existence was demonstrated in 29 per cent. Sometimes, however, the numbers detected were very few, not more than one or two in a slide, but in the greater number of cases they were very numerous, every slide containing several hundreds.

Being anxious to ascertain precisely the species of rats in which these organisms were found, I consulted an accomplished naturalist, Dr. John Anderson, Superintendent of the Indian Museum, and he was so good as to identify the specimens for me from time to time. The result has been that it has been definitely ascertained that these organisms may be found in two species, *viz.*, *Mus decumanus* and *Mus rufescens*.

It would appear that they are not found in mice. I have examined the blood of a large number, but never detected any organisms of the kind; nor have I seen them in any animals other than rats.

It is possible that these minute organisms ought to have been described in the part of this paper devoted to the description of microphytes, as they present many features in common with motile organisms undoubtedly of vegetable origin; on the other hand, taken as a whole they appear to approach more closely to the forms of life usually classified as protozoa; such, for example, as several of the species of Dujardin's genus *Cercomonas*. It should, however, be noted that many believe that these organisms are zoospores and not animalcules.

The nearest approach to a description of these hæmatozoa which I can find is in

a recent paper by Bütschli,* in which he refers to a flagellated parasite which he has often observed in the intestinal canal of a free nematode (*Trilobus gracilis*). He refrains from giving it a name owing to the uncertainty which exists with regard to organisms of this kind. He generally found them in large numbers, often forming stellate colonies owing to their being attached by their non-flagellated-ends. They readily became detached and then presented a somewhat spindle-shaped body, about 11μ in length and with a somewhat thick flagellum about double this length, so that the total length of the protozoon would be 33μ, something more than half of the length of the flagellated organism found in the rat's blood. Near the base of the flagellum of Bütschli's protozoon a contractile vacuole could be distinguished, but I have not been able to detect any such vacuole in these rat-hæmatozoa.

Seeing that the blood of such a large proportion of rats contain these organisms, I can hardly suppose that their existence has hitherto escaped notice, unless it be that rats in Europe do not harbour like parasites. Davaine† in the recent edition of his work makes mention that M. Chaussat had found minute nematodes in the blood of a black rat (*Mus rattus*), but I have not seen any nematode in the blood of rats in this country. In the tissues, bladder, etc., of rats such parasites are very common, but their description does not come within the province of this paper.

The nearest approach to the flagellated hæmatozoa of rats which I have seen described is to be found in a foot-note in Dr. Bastian's "Beginnings of Life,"‡ where it is stated that Dr. Gros had seen minute worms (*vermicules*) in the blood of a field-mouse (*mulot*) which were so numerous as to cause the blood to present an animated appearance; and that the blood of the mole was often found to be in a similar condition. They were so small as to be barely visible under a power magnifying 400 diameters. I have not been able to obtain any minute description of these *vermicules*, but I anticipate that it will be found that they closely resemble the flagellated protozoa found in the blood of Indian rats.

With regard to the health of the rats in which these flagellated organisms were detected, there was nothing to suggest in any way that they were less healthy than others not so affected, and I have repeatedly kept rats for a considerable time for the purpose of observing whether any special symptoms would be manifested suggestive of the existence of such organisms in the circulation. It should be mentioned that it frequently happened that the rats caught in a particular room would be affected, whereas the blood of rats in another part of the building would not contain them. The servants had ultimately come to recognise this, as, whenever they learnt that a particular rat's blood contained the desired organisms, they diligently endeavoured to secure the rest of the family.

When it is considered that thousands of active beings of this character can exist

* "Beiträge zur kenntniss der Flagellaten und einiger verwandten Organismen:" *Zeitschr. für wissensch. Zoologie.* Band XXX, Heft 2, Taf. XI, Fig. 9, Jan. 1878.

† Traité des Entozoaires, Edit. II, pp. 11, 957: 1877. Leuckart's "Parasiten," vol. ii, p. 636.

‡ Vol. ii, p. 338: 1872.

in the blood without in any appreciable manner affecting the health of their host, and when it is further considered that these organisms must consume at least as much, if not far more, oxygen than bacteria, bacilli and spirilli, it becomes difficult to understand how it comes about that to a like action on the part of the latter is ascribed the asphyxia and the other morbid conditions which characterise death from splenic disease and allied affections.*

B.—Protozoa in the Blood of healthy Frogs, Deer, etc.

Scarcely higher in the developmental scale is the protozoon described by Professor Ray Lankester as being found in the blood of frogs.† These organisms were at first taken by this distinguished observer to be exceptionally active white blood-corpuscles, as they are but very little smaller than the red corpuscles of the frog's blood. Owing to the protozoon's great activity there was some difficulty in making out the nature of its locomotive organs until it had been killed by acetic acid vapour. It was seen to be a pyriform sac, coarsely striated, and containing a pale, clear nucleus. One portion of the sac is spread out into a broad thin membrane, which at one end produced a flagellum; the former undulates in a series of waves, which, with the action of the flagellum, "tend to urge the animal in a wide circle" (Fig. 56, *a*).

Numerous oblong bodies (Fig. 56, *b*) were also noticed in the blood of one frog attached in many cases to the end of the red blood-corpuscles. These, it is considered, judging from their being associated with the parasite, may be genetically connected with it.

Fig. 56.—*a*, Undulina ranarum; *b*, Minute oblong bodies associated with it. (Magnified by Hartnack's No. X objective. Original figure reduced to half size: After Lankester.)

Professor Lankester considers it improbable that this hæmatozoon has not been previously seen and described. He speaks of it as a mouthless infusorian closely allied to the *Opalinidæ*, but possessing no cilia, the latter being replaced by an undulating membrane and a flagellum It is therefore believed to represent the type of a new group of infusoria, and is named *Undulina ranarum*.

* M. Toussaint commences a recent paper, submitted to the French Academy, with these words: "Les expériences entreprises dans ces derniers temps ont démontré que la bactéridie est la cause du charbon, 'La bactéridie provoque l'asphyxie en enlevant aux globules l'oxygène nécessaire à l'hématose;' telle est la conclusion des expériences de MM. Pasteur et Joubert. Telle était aussi l'explication que j'avais cru devoir déduire des faits contenus dans la Note que M. Bouley avait bien voulu présenter en mon nom a l'Académie le 14 août dernier."—*Comptes Rendus*, t. lxxxv, p. 1076; Dec. 3, 1877.

On the other hand, Professor Virchow is unable to accept such a doctrine as is referred to by M. Toussaint. In some experiments conducted with charbon-material by this celebrated pathologist it was found (among other things) that the proportion of bacteridia present in the blood at autopsies bore no relation to the severity of the disease, so that for this and other reasons Virchow came to the conclusion that the special morbid material must be of the nature of a chemical poison. Op. cit., page 30.

† *Quarterly Journal of Microscopical Science*, vol. xi, p. 387; 1871.

Some years ago Auguste Rättig* described an "amœboid" organism which he had found in the blood of some frogs. Judging from the description and figures, it is evidently identical with Lankester's *Undulina*. Lieberkühn† appears to have described a somewhat similar protozoon in the frog's blood under the designation *Amœba rotatoria*, and which, according to Waldeyer,‡ was named *Trypanosoma sanguinis* by Gruby.

In the same paper Rättig describes another hæmatozoon, which he had often seen in the capillary vessels whilst examining the frog's mesentery during the months of May and June; they were of elliptical form and of granular aspect, with a length equal to the long diameter of about $1\frac{1}{2}$ of a frog's red blood-corpuscles. Channels with cæcal terminations could be distinguished in them; these, however, disappear in the course of a few hours, and thus the appearance of the animalculæ becomes completely changed (Fig. 57, *a*, *b*). They moved rapidly in the serum, propelled by means of cilia placed along the dorsal aspect of the body, and it was observed that they could travel in both directions of the blood-current. It would appear that these organisms were only found in frogs obtained from certain localities. Occasionally specimens were observed which

a *b* *c*

Fig. 57.—*a*, *b*, *c*, Changes undergone by a protozoon found in the blood of frogs in the course of a few hours: Magnified 500 diameters. (After Rättig.)

manifested a distinctly striated appearance, in which no canalicular system could be distinguished, and whose movements were somewhat slower. These are considered to be the same parasite as the last described, as occasionally this change of appearance has been seen to take place during the time of observation (Fig. 57, *c*).

Akin to the foregoing hæmatozoa of the frog, though considerably larger, are those which were described by Dr. Boyd Moss in 1871 as being found in the Ceylon red deer (*the Muntjac* of India).§ Dr. Moss speaks of them as oval, ciliated bodies, capable of swimming actively in the serum, two or three being seen at a time in the field of a $\frac{1}{8}''$ objective. They are colourless and perfectly translucent; and all present two or three large ova-like spherical bodies "towards the posterior half, the remaining portion being filled with small cells and granules." The anterior pointed half of the

* "Ueber Parasiten des Froschblutes;" Inaugural-Diss. Berlin, 1875.

† Lieberkühn: "Ueber Bewegungserscheinungen der Zellen;" cited by Rattig, op. cit., p. 16. *Vide* also Davaine's "Entozoaires," II Edit., p. XVI (foot-note).

‡ Virchow and Hirsch's *Jahresbericht*, vol. i, p. 96, 1875.

§ Monthly Microscopical Journal, October 1871.

body is furnished with cilia, which "are raised on a substructure of a wave-like appearance" (Fig. 58). They were found on three occasions apparently each time the blood of this deer was examined. Unfortunately measurements have not been furnished, but they are described as being too large to pass through the capillary vessels. In the same plate a figure is given of the red blood-corpuscles of the same deer, and their diameter is stated to be $\frac{1}{6500}$ inch. If the figures of the hæmatozoon have been drawn to the same scale as the corpuscles, it may be inferred that the length of the parasites would correspond to the diameter of about 20 human red blood-corpuscles, or about ·16 mm., and the greatest width about ·1mm.

They will continue alive under the microscope for about an hour. After death three bands, resembling muscular fibre, are seen to traverse the body longitudinally, but these are not visible during life.

It does not appear that either the frogs or the deer had been in any way inconvenienced by the presence of these protozoa in their circulation.

Protozoa have also been found in the blood of the carp by Wedl. They are spoken of as being *Globularia radiata*, and were observed to have been especially abundant during the summer.*

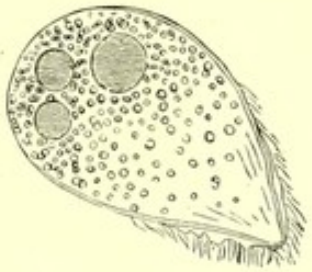


Fig. 58.—Protozoon obtained in the blood of a deer. Original figure reduced to half size. (After Boyd Moss.)

The foregoing section contains a brief account of all the protozoa of this character, regarding which I have been able to collect information, unless it be considered that the organisms referred to by M. Davaine in his well-known work on parasites as having been observed by Klencke and Gros belong to the same category. According to M. Davaine, Klencke detected in the blood of a person suffering from vertigo "des animaux semblables aux infusiores;" and M. Gros is said to have obtained them in the blood of persons affected with syphilis.† This description is not sufficiently precise to warrant any opinion being expressed as to their character.

The remaining hæmatozoa of man and animals belong, so far as I am aware, to the helminthic group. As it is proposed specially to refer only to such of them as are of microscopic dimensions, their description need not occupy more than a few pages.

III. HELMINTHIC HÆMATOZOA OF MAN AND ANIMALS.

A.—Trematoid Hæmatozoa.

With regard to the helminths which have been found in the blood, it may be stated generally that, with one exception, they all belong to the nematoid group. The excep-

* *Jahresbericht* Von. J. Victor Carus, *Zeitschr. f. d. wissen. Zoologie*. Band VII—"Supplement-Heft." 1856, p. 35.

† Op. cit., II Edit., p. 317.

tion is *Distomum hæmatobium*, a fluke-parasite discovered by Bilharz * in the venous system of the abdominal viscera of persons in Egypt in 1851; in 1857 by Dr. Spencer Cobbold in the portal vein of a monkey;† and lately by Dr. Sonsino ‡ in like situations in oxen and sheep. These parasites appear to affect about a third of the entire population of some parts of Egypt. The female is a filiform parasite something less than an inch in length; and the male thicker, but only a little than half the length of the female. The anatomy and the pathological significance of these worms are so well known that it is not necessary to give details, especially as nearly every text-book of medicine supplies full information regarding them.

B.—Nematoid Hæmatozoa of Animals.

The nematoid hæmatozoa are far more numerous, although to some extent the number has been increased by the circumstance that nematoid embryos which have accidentally got into the circulation have been classified as hæmatozoa, though, in such cases, the blood can scarcely be considered as their normal *habitat*.

These parasites have been found in nearly all classes of animals either in the mature state, or as embryos, or as both combined.

Not uncommonly the parents may be found in the tissues and the embryos in the blood. Vogt, for example, found two large filariæ, over two inches in length, in the ventral cavity of a frog. These were distended with ova and embryos, the latter being also found in the blood of the frog. §

Under the designation *Filaria cordis phocæ* M. Joly describes numerous female nematoid parasites which he had discovered in the heart of a seal, 6″ to 8″ in length, and about ″ in width, and which were stuffed with ova and embryos. Towards the anterior third of the body the latter were free and measured from $\frac{1}{400}$″ to $\frac{1}{350}$″ (·06 to ·07 mm.) in length. The male was not seen.‖

Dr. Cobbold also describes a parasite, *Filaria hebeta*, which was found in the heart of a seal. The length of the female in this case also was 6 inches; that of the male, distinguished by the possession of a spirally curved tail, was up to 4 inches. The embryos were considerably larger than the measurements given by M. Joly as those of his parasites, being $\frac{1}{90}$″, and about the width of a human red blood-corpuscle.¶

Wedl found a filaria with a broad head and filamentous tail in the blood of a whale, together with a peculiar body ("aus acht in einander geschobenen Ringen bestehende Körperchen") double the length of a blood-corpuscle.

* *Zeitschr. für wissen. Zoologie.* Band IV, 1853.

† "Entozoa: an Introduction to the Study of Helminthology," 1864.

‡ "Sugli Ematozoi come contributo alla Fauna Entozoica Egiziana," 1877.

§ "Archiv. für Anat. und Physiol.," 1842, S. 189; cited by Leuckart, "Die Menschlichen Parasiten;" Band I. p. 52.

‖ *Annals and Magazine of Natural History*, vol. I, 1858.

¶ Proceedings of the Zoological Society, Nov. 1873, p. 741.

This observer likewise, on two occasions, found nematoid worms in the blood of a carp (Cyprinus tinca). They were $\frac{6-8}{10000}$ of a Vienna inch in length and ·0001 in width.*

It has long been known that the blood of many birds is infested to an extraordinary extent with the embryos of nematoid helminths. The first record of them is by Schmidt, who appears to have discovered them in 1826.† They have since been frequently described; and, according to Virchow,‡ they have also been found by Herbst in the blood of hawks, jackdaws, jays, etc. Borell § writes regarding a condition which he describes as "Trichiniasis of the Crow." The parasites found were ·13mm. in length by ·004 in width, but as they appear to have, for the most part, only been found in the blood vessels, the term "trichiniasis" is scarcely applicable; moreover, the worm is manifestly not a trichina. It is worthy of special note that specimens of precisely the same size as those in the blood were also found in the aqueous humor and in the *corpus vitreum* of one eye. Sonsino ‖ has likewise often found them in the crow in Egypt, and states that they are $\frac{1}{8}$ of a millimeter in length. One of the crows in which he found these embryos contained three examples of *Filaria attenuata* in its ventral cavity. Ecker suggests a genetic connection between the latter and the former; ¶ and Leuckart, in his standard work on the Parasites of Man, appears to coincide in this view.**

Fig. 59 . × 500. Filaria from the blood of the Indian crow.

I have examined a considerable number of the ordinary Indian crow (*Corvus splendens*), and have found that the blood of nearly half of those which have come under my notice have contained embryo hæmatozoa of this character. Sometimes they are in such numbers as to make it a matter of surprise how it is possible that any animal can survive with so many thousands of such active organisms distributed throughout every tissue of its body. The birds did not appear to be affected in the slightest degree by their presence. In their movements they are very similar to the nematoid embryos found in man; they are, however, considerably smaller, and manifest no trace of an enveloping sheath (Fig. 59). Those measured by me were found to be ·09 mm. in length by ·004 in width, which is, roughly, more than one-third the length and one-half the width of the embryo of *Filaria sanguinis-hominis*, to be subsequently referred to.

* Wedl cited by Carus, loc. cit.

† Gervais and Van Beneden: "Zoologie Medicale:" 1859; quoted by Sonsino, op. cit.

‡ Virchow's Archiv, vol. lxv, 1875, p. 400.

§ Idem, page 399.

‖ Op. cit.

¶ Diesing's "Systema Helminthum," vol. xi, pp. 266-7, 1851.

** "Die menschlichen Parasiten," Band I, p. 52; Band II, p. 614; Leipzig, 1876.

They were not in the least affected on the addition of half per cent. salt-solution, and continued to manifest active movements in it for from 6 to 8 hours. A drop of blood containing numerous hæmatozoa was placed on the slide arranged for the application of electricity; and an induced current of considerable force was passed through it for two hours without the slightest appreciable effect on the filariæ being observed. As the current applied was stronger than could be tolerated by a man for any lengthened period, it would seem that the application of such a remedial agent to persons affected with organisms of a like character is not likely to be followed by any satisfactory results.

The blood of several of the crows examined was, when perfectly fresh, strained through linen, but no parental form was caught on the strainer, nor were any ova to be detected.

In Solipeds—the horse, ass, mule, etc.—aneurismal dilatations of the mesenteric arteries are very commonly observed, the result of an *arteritis* set up by the palisade worm (*Sclerostomum equinum*) during one of the stages of its growth. As, however, it does not appear to take up its abode in the blood itself, the matter does not call for further reference here. It would seem, however, that occasionally the blood of the horse does contain *bonâ fide* nematoid hæmatozoa. Leuckart * refers to a case of the kind as having been observed by Wedl. in which the nematoid hæmatozoa were associated with the presence in the abdominal cavity of *Filaria papillosa*, the ordinary worm of the anterior chamber of the eye in horses, etc.; and Sonsino † found three minute nematodes in the blood which was drawn from the jugular vein of a horse. They were ·23 mm. in length, the length being to the width as 37 to 1, and in general appearance they resembled the hæmatozoa of the crow.

Of all animals which have been found to harbour hæmatozoa, the dog, perhaps, takes the first place. Dogs affected in this manner have been observed in nearly all parts of the world, notably in China, India, and some of the southern parts of Europe. It is, moreover, probable that the embryos of different species of nematoids are found in this animal's circulation: that mature helminths of different species are found in it is a well-ascertained fact.

The interest in this subject dates from the observations which were made more than twenty-five years ago by MM. Gruby and Delafond, which went to show that 4 to 5 per cent. of the dogs in France harboured microscopic nematodes in their blood. In a paper entitled "The Pathological Significance of Nematode Hæmatozoa" published by myself in 1874,‡ it was pointed out that more than a third of the pariah dogs of this country are similarly affected; and Dr. Patrick Manson has shown that this kind

* Op. cit., vol. ii, p. 635.

† Op. cit.

‡ *Tenth Annual Report of the Sanitary Commissioner with the Government of India*, App. B, 1874; *Indian Annals of Medical Science*, No. XXXIV, July 1875; also, in part, in *Quarterly Journal of Microscopical Science*, 1875, page 533 of this volume.

of parasitism affects at least an equal proportion of dogs in China.* The embryos which have been found in the dog's circulation appear to correspond as to size, form, and character of movements, irrespective of the countries in which they have been found; and, were it not that discrepancies exist as to the relative prevalence of the mature forms of the nematoid parasites which have been found in different countries, an easy decision might be arrived at as to the parental form in all. As this is a subject having considerable bearing on the elucidation of the genetic relations of the embryos of an allied condition in man, it is necessary that the matter should be closely scrutinised.

Two, or possibly three, mature parasites have been observed as being more or less frequently associated with the presence of embryos in the blood of dogs: they have been found in the heart, in the arterial walls, etc., and in the subcutaneous tissues.

The earliest record of such mature parasites associated with the existence of embryos is found in the account of MM. Gruby and Delafond's experiments, where it is stated that on one occasion (out of a total of 480 dogs the blood of 20-24 of which had contained embryos) they found six white, filiform worms, in the right ventricle. They were from five to eight inches in length (14 to 20-24 centimeters) and from $\frac{1}{25}$ to $\frac{1}{16}$ inch in width. Two of the specimens were male and four female, the latter being full of ova and embryos; the embryos identical in appearance with those found in the blood.† This observation, as regards Europe, appears to have remained unique for many years, but latterly MM. Galeb and Pourquier say that they have found the heart of a bitch stuffed with such adult filariæ, the female specimens being 30 to 32 centimeters in length; and, the animal being pregnant, they further discovered that the blood of a fœtus, which was examined, contained many "embryons hématiques." The male examples of the parasite were thinner than the female, and only half the length.

These mature worms are considered to be identical with Leidy's *Filaria immitis*,‡ for a very careful description of the minute anatomy of which we are indebted to Brigade Surgeon Welch, F.R.C.S. §; as also to Dr. Cobbold ‖ and Dr. Manson.¶ They appear to be extraordinarily common in China. Manson found them, for the most part, coiled up in the right ventricle, sometimes extending through the tricuspid valve into the auricle, and even into the superior vena cava, and very generally through the semilunar valves, far into the pulmonary artery and its branches. He never found them in any other vessel, though carefully sought for. The female specimens measured from 8″ to 13″ in length by $\frac{1}{30}$″ in width; and the male, recognised by its corkscrew-like tail, from 5″ to 7″ in length and $\frac{1}{40}$″ in width.

* "Report on Hæmatozoa" in China *Customs Medical Reports*, vol. xiii. Shanghai, 1877.
† *Comptes Rendus*, t. xxxiv, pp. 11—13, 1852.
‡ Proceedings of the Academy of Natural Science, Philadelphia, vol. v, 1850-51.
§ *Monthly Microscopical Journal*, October 1873, p. 157.
‖ Proceedings of the Zoological Society, November 1873.
¶ Op. cit., pp. 1—11.

It seems somewhat strange that, notwithstanding the marked prevalence of embryo-hæmatozoa, the *Filaria immitis* has not, so far as I can learn, been recognised in India. I have often searched specially for it, but in vain. The only mature parasite which appears to affect the circulatory system of dogs in this country is the *Filaria sanguinolenta*, a description of which, together with an account of the pathological changes which are caused by it during its development in the walls of the aorta and adjacent tissues, was published by me in 1874.* This Filaria may be readily recognised by its pink hue, when fresh, and by many other characters which need not be specially referred to on this occasion. It does not appear to be viviparous, for, although living Filaria may readily be pressed out of mature ova, I have never found free embryos either in the body of the female parasite, or in the fluid contained in the pouch in which it is usually lodged, although an abundance of free ova are always present. Notwithstanding the circumstance that this is the only mature helminth which I have found associated with the embryo-hæmatozoa in India, I cannot believe that there is a genetic connection between them, for it frequently happens that the mature worm may be present in abundance unassociated with blood embryos of any kind, and sometimes it is found that the latter exists without any trace of the former.

Recently a very interesting observation bearing on this subject has been made by Ercolani—an observation which may serve at some future period to throw some light as to the origin of the microzoa of dogs in this country.† Ercolani has, on two occasions, found sexually mature worms in the subcutaneous cellular tissue of dogs in Italy. In one of the cases they were very numerous and were associated with embryos in the blood. The writer suggests that possibly still other mature parasites may eventually be discovered, as the embryos in the blood are probably not derived from the same species. I have, on several occasions, endeavoured to find the mature form in the cellular tissues of various parts of the body of dogs, but have not been successful. This, however, by no means implies that such thread-like creatures were not present.

C.—Nematoid Hæmatozoa of Man.

There remain now to be considered the nematoid hæmatozoa which have been found in the circulation of man. The literature of this subject dates from the period of the publication in 1872 of a paper submitted by myself to the Government, entitled "On a Hæmatozoon in Human Blood."‡ Towards the beginning of July of that year, I found nine minute nematoid worms in a state of great activity on a slide containing a drop of blood from the finger of a Hindoo. They were about $\frac{1}{80}''$ in length, and $\frac{1}{3580}''$ in width, or slightly less than the average diameter of a human red blood-corpuscle (·3 mm. × ·007 mm.).

* Loc. cit., page 503 of this volume.

† A notice by Paul Güterbock in Virchow and Hirsch's *Jahresbericht* for 1875, vol. i, p. 379.

‡ *Eighth Annual Report of the Sanitary Commissioner with the Government of India*, 1872. Also *Indian Annals of Medical Science*, vol. xvi, and page 503 of this volume.

Unfortunately, after the observation had been made the man could not be found so as to be questioned as to his past history, so that the pathological conditions which might have been associated with this, the first recorded instance of the existence of nematoid hæmatozoa in man, must continue in obscurity.

This observation was, however, followed by several others which have gone to show that the presence of this particular helminth in the blood is very generally associated with chyluria and with an allied affection known as lymph-scrotum or nævoid elephantiasis. The extent of this connection may, in some degree, be inferred from the circumstance that whereas filariæ may occasionally be observed in the blood of persons apparently free from disease of any kind, they are, so far as my personal experience goes, invariably present when either of these diseases exist. It must be recollected, however, that the search for them sometimes involves very considerable labour.

These parasites, or parasites very closely allied, have now been found in the blood of man in many parts of the world. Dr. Prospero Sonsino,* in January 1874 (having no knowledge of previous observations of a like character), found them in the person of a Jew-lad at Cairo. They have been found in China by Dr. Patrick Manson † of Amoy, and in Australia by Dr. Bancroft ‡ of Brisbane. They have also been found in the blood in Brazil; and, within the last few weeks, in England, by Dr. Hoadley Gabb of Hastings.§

In considering the possible relation which may exist between the several parasites which have been found in different latitudes, it will be well to bear in mind the history of somewhat similar organisms in the circulation of dogs, a brief epitome of which has been given above. There is another matter to be taken into consideration as regards the identification of like parasites in man,—namely, their association with diseased conditions. Are these conditions invariably of the same general character in all countries? If so, it would be sufficient to show that a distinct relation of some kind existed between the disease and the parasite; but if it be found, notwithstanding the existence of a general correspondence between them, that nevertheless minor differences were more or less constantly present, this would indicate either that some slight difference existed in the parasite itself or that it bore no casual relation to the disease.

It so happens that nematoid hæmatozoa are found associated with a disease which, whilst manifesting a close general resemblance in different countries, is nevertheless characterised by a marked difference. In Asia, or at least in India, it is known by its most characteristic appearance, *viz.*, milky or chylous urine; whereas in Africa and South America it is described as the "hæmaturia" of various localities, or as "hématurie chyleuse" or "graisseuse," a term doubtless adopted on account of its being a more correct description of the malady than chyluria. In India, however, although the term may be more or less

* "Richerche intorno alla Bilharzia hæmatobia in relazione colla ematuria endemica dell' Egitto e nota intorno ad un nematoideo trovato nel sangue umano." Naples, 1874.

† Op. cit.

‡ "On Urinary and Renal Diseases," by W. Roberts, 3rd Edit., 1876, p. 342.

§ *The Lancet*, June 22, 1878, *p.* 921.

applicable at some period or other of the disease, it is nevertheless not so appropriate in the great majority of the cases, and, indeed, in some instances is wholly inappropriate, as occasionally no marked traces of red colouring matter can be detected in the urine from the beginning to the close of the attack. There is an instance of this kind under my observation at present (a European born in the country) suffering from a third attack, who has never detected the slightest trace of blood at any time. It is of importance that this feature in the character of the disease according to its geographical distribution should be borne in mind, as it may hereafter be found that what at present are generally considered as merely two phases of one malady may each have a distinctive etiology.

When in March 1870 * I detected a microscopic nematoid in urine of the latter character, I was under the impression that no nematoid of any kind had previously been found in any urine which could not be attributed to accidental circumstances. It proved, however, that the late Dr. Otto Wucherer had already found a parasite of a like character in 1868 in "*Hæmaturia Braziliensis*," and had forwarded specimens to Prof. Leukart for identification.† Dr. Jules Crevaux succeeded in confirming Wucherer's discovery by finding (27th July, 1870) similar helminths in the urine of a young creole affected with a like disease.‡ It is possible that the parasite discovered by Wucherer and described by him in December 1868 § may prove to be identical with the one found by myself in March 1870; in such an event it will be necessary to seek for some clue, other than specific differences in the helminths, to account for the circumstance that the disease with which they are associated presents different characters.

Fig. 60.—*Trichina cystica:* Embryo of an oviparous nematode, obtained in urine. (Reduced from Dr. Salisbury's figure representing it as magnified 1,000 diameters to = × 300 diam.)

In order to complete the sketch of the history of nematoid urinary parasites of this period it will be necessary to refer to two other observations, as it may be of assistance to future writers in deciding (1) as to the number of such helminths that may be found in the urine of man, and (2) whether any of them should be considered as pseudo-parasitic merely. In 1868 Dr. Salisbury published an account of a parasite which he had found associated with ova, in the urine of an insane old lady suffering from severe "cystinic rheumatism," and affected with partial paralysis of the bladder and of other parts of the body. A drop of urine frequently contained 10 to 15 ova. It was *not* a case either of hæmaturia or chyluria, although it is sometimes erroneously stated that she was suffering from the latter disease. This impression has arisen from the fact of *cystinuria* having been confounded with chyluria, two totally different disorders. The helminth is described as *Trichina cystica* (Fig. 60).

Writing in 1872, Dr. Cobbold, after describing the history of a little girl who had

* *Annual Report of the Sanitary Commissioner with the Government of India*, 1870. *British Medical Journal*, 19th November, 1870, and page 19 of this volume.

† Leuckart's "Parasiten," Band ii, p 640.

‡ Idem; and Journal de l'Anatomie et de la Physiologie, t. xi, 1875.

§ Gazitta da Bahia, December 1868.

been suffering from hæmaturia associated with the *distomum hæmatobium*, refers to the circumstance that he obtained from the patient some other urinary parasites *in the egg condition*.* "On five separate occasions," writes Dr. Cobbold, "I obtained one or more specimens of the eggs or embryos of a minute nematode. In one instance there were about fifty of these ova in the urine, their embryonic contents being well developed, and in a state of activity. Usually they were all in this advanced condition; but on the 25th of July, 1870, several were observed in much earlier stages of development." The fully grown eggs gave a longitudinal measurement of $\frac{1}{500}''$ by $\frac{1}{1000}''$ in breadth. Judging from the description of the ova and their contained embryos, it would seem that the parental form must have been oviparous. The embryos, when freed artificially from the egg, measured $\frac{1}{300}''$ in length by $\quad''$ in breadth. On two occasions free dead specimens were observed which had been lying in water some time, and these measured $\frac{1}{150}''$ by $\frac{1}{3000}''$. The parents of the patient had mentioned that the latter had "passed three small vermiform entozoa by the urethra."*

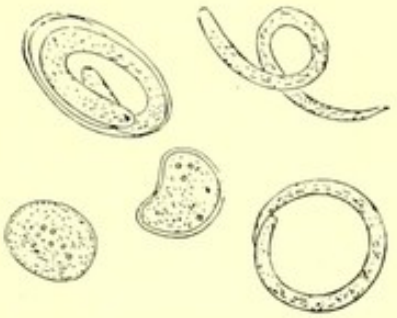


Fig. 61.—Ova and freed embryos of an oviparous nematode; obtained in urine. (After Cobbold.)

Dr. Cobbold writes: "I have been thus particular in recording these facts, because future discoveries may enable us to identify the species of nematode to which these ova are referable. I know only one set of observations on record which refer to this same species of parasite." The parasite referred to is the above-cited *trichina cystica*. As it may be a convenience to future observers to be able to judge of these matters for themselves in the absence of the original papers, I have reproduced Dr. Cobbold's illustrations, together with a reduced outline of Dr. Salisbury's figure. The reduction has been affected by means of a camera lucida, so as to represent the helminth as magnified 300 diameters instead of 1,000 as in the original. This will facilitate comparison with Dr. Cobbold's figure representing his nematoid ova parasites† (Fig. 61). Notwithstanding the discrepancy in size, Dr. Cobbold considers that the helminths are referable to one and the same species.‡ They are both manifestly the offspring of some oviparous nematode; further than that it is, I think, hardly safe to carry the comparison.

The figures which also serve to elucidate another matter, as Dr. Cobbold has since

* During the last seven years I must have examined the sediment of very many gallons of chylous urine, but never observed any ova of nematodes, though, from time to time, I have found many hundreds of embryos.

† *British Medical Journal*, July 27, 1872, page 92.

‡ *London Medical Record*, No. i, vol. i, 1873; *The Lancet*, July 13, 1878, p. 64.

asserted that his parasite is not only identical with Dr. Salisbury's but also identical with the *Filaria sanguinis hominis*,* a figure of which under a somewhat like magnifying power will be found in Plate XLII (Figs. 3 and 5). Dr. Douglas Cunningham several years ago pointed out that such a view was untenable;† moreover, the mature *Filaria sanguinis hominis* is not oviparous but viviparous.

D.—Changes undergone by the Embryos of Nematoid Hæmatozoa when ingested by the Mosquito.

It would occupy too much space to attempt an epitome of all that has been written regarding the *Filaria sanguinis hominis* and the somewhat numerous diseases which have been ascribed to its influence, so that for the present the foregoing must suffice. It remains to be considered how it is that the embryos get into the circulation and what becomes of them afterwards. A most important step towards the solution of these queries has recently been made by Dr. Patrick Manson of Amoy.‡ He has shown that, immediately after a mosquito has fed itself on the body of a filaria-affected individual, the insect's stomach will contain living examples of the hæmatozoon; and that the latter will attain considerable progress towards maturity therein, in the course of a few days. It is believed that it then escapes from the mosquito when the latter dies in the water to which it betakes itself, and filariæ thus find their way into the human body. Dr. Manson's highly interesting paper gives a full account of the various development stages, together with figures of the objects as they appear from time to time.

I have repeated many of Dr. Manson's experiments, and have been able to satisfy myself, from personal observation, that his statements as to what occurs in China may, in most particulars, be made applicable to India also. I had on many occasions, examined the stomachs of mosquitoes and of other suctorial insects in a cursory fashion during the last few years, but had never detected parasites resembling the *Filaria sanguinis*. When, however, I learnt of Dr. Manson's success, I proceeded to make examinations in a systematic manner, and found, to my surprise, that 14 per cent. of the insects, caught at random and then examined, contained such embryos.§ It became, therefore, manifest that filarious blood must be a tolerably common occurrence.

At first I was not successful in being able to detect any but disintegrative changes in the ingested parasite owing to the circumstance that I had carefully restricted the examination to the contents of the stomach only. This was done in order to diminish the risk of confounding the various stages which the embryo-filariæ might undergo with some other parasites which might exist among the tissues of this, as of other insects. The parasites were, in fact, found to be digested. Leuckart‖ mentions that

* *London Medical Record*, No. I, vol. i, 1873: *The Lancet*, July 13, 1878, p. 64.
† *The Lancet*, June 14, 1873, p. 835.
‡ China *Customs Report*, No. XIV, 1878.
§ Proceedings of the Asiatic Society of Bengal, March 1878, p. 89.
‖ Op. cit., Band II, p. 706.

a similar result was observed by Fedschenko to follow the ingestion of dracunculus-embryos in the stomach of the *Cyclops*. The latter is believed to serve as an intermediary host for the development of the guinea-worm, the embryos getting into the body of the Cyclops by piercing the cuticle. When the embryos are swallowed they are digested.

In the course of the foregoing observations it was observed that all the mosquitoes captured in one of the servants' houses contained hæmatozoa of the same character, and it was found that one of the five persons dwelling in this house harboured filariæ in his blood. The man had been many years in the place and is not known to have suffered from any special disease.

The circumstance of such a constant supply of filarious mosquitoes, of tolerably certain history, materially simplified the course of investigation, which, briefly told, was as follows:—

Insects were caught early in the morning in the room in which this person had slept, just as Dr. Manson had done. Some were placed in bell glasses standing in water, others in test-tubes containing a little water at the bottom and covered with a strip of muslin. These were duly labelled and set aside for periodical examination.

When the insect was examined with recently ingested blood in its stomach, it was found that the hæmatozoa, when present, did not differ materially from the aspect presented by them when extracted directly from blood of its previous host (Plate XLII, Fig. 5), although, not unfrequently, parasites would also be seen which either belonged to a more advanced stage of the one under consideration, the result of a previous ingestion of filarious blood, or belonging to a totally different kind. There is always, therefore, a risk of confusing different parasites in the same insect. Repeated examinations at the same periods tend, however, to minimise this source of errror. During the first twenty-four hours no marked change takes place in the form of the organisms.

On the second day, however, it will probably be seen that the blood has, to a considerable extent, undergone digestion, and the stomach will no longer manifest the distended condition of the first day. Probably a few altered hæmatozoa will be observed in it moving very languidly, presenting the appearance of partially disintegrated fungal filaments when the movements are not manifested. Some of them may be actually dead; these will be found to be stained by eosin solution very readily.

Between the second and the third day further changes occur, but in order to be able to follow these it will be necessary to examine the other tissues of the insect, as possibly the stomach may contain none; it will, however, probably be found that some of them have migrated into the tissues immediately outside this viscus. It will now be observed that some of the parasites have become considerably thicker (Fig. 7); and occasionally specimens will be seen with the tail presenting the appearance of a lash (Fig. 9); the movements are still very sluggish.

About the fourth day it is probable that examples in various stages of growth

will be visible, rendering it extremely difficult or impossible to state precisely what it is that actually does take place; at least hitherto I have not been able to satisfy myself. About this period, however, I have sometimes seen bodies, apparently composed of precisely the same material as Figs. 6. 7, 9, undergoing something so very like cleavage (Plate XLII, Fig. 8) that I hesitate to state that this act is not one of the stages in the development of the filaria. The figure given (No. 8) is very carefully sketched, and, like all the others, accurately to scale. It will be noticed that one end is partially hidden by some granular matter. This I was not able to press away from the preparation. Other preparations of a like kind were also more or less hidden by granular matter, and in some cases (unassociated, however, with any indications of fission) the parasite appeared to be covered with an encrustation. With regard to the process of division suggested by the appearance of No. 8 I can offer no opinion; it is quite possible that it forms a part of the developmental changes undergone by some other parasite,—such, for instance, as a gregarine. About the fourth day there will also be seen short, thick bodies (very appropriately described Dr. Manson as "sausage-shaped"), almost perfectly still (Fig. 10), with a faint indication of a mouth; and, in some of them, a faint line may be detected suggestive of a commencing intestinal canal; the escape of a few granules on slight pressure towards the other, usually thicker, end, suggests the existence of an anal aperture. The chief difficulty which I have experienced in following these changes is to account for the transition of form at Fig. 7 to that represented in Fig. 10. They are all, up to this figure, sketched as magnified by 300.

The larval forms at Fig. 10 now rapidly increase in size, and gradually acquire a more elongated outline, and between the fourth and fifth days they may be found preenting the form shown at Fig. 11. The last figure, it will be noticed, is magnified 100 diameters only, and the length of the larvæ, therefore, is almost three times that of those delineated at Fig. 10. They also manifest greater activity.

The highest stage of development which has come under my notice is that figured at 12 as seen magnified 100 diameters. The anterior and posterior portions of a similar one, magnified 300 diameters, are delineated at Fig. 13. This measured $\frac{1}{33}$ of an inch in length, and its width towards the middle was $\frac{1}{640}$; near the anterior and posterior ends they measured $\frac{1}{800}''$ across. The dimensions of another specimen which I measured were $\frac{1}{32}''$ in length by $\frac{1}{1000}''$ in width at the broadest part. Dr. Manson mentions that he has on four occasions observed larger specimens than these.

Notwithstanding their activity and apparently robust condition, they nevertheless are extremely fragile, very slight pressure of the cover-glass being sufficient to crush them. When examined in the unbroken condition it is only with difficulty that the alimentary canal can be distinguished beyond the junction of the œsophagus with the intestine, but when carefully ruptured (as in Fig. 12) the tube may be distinguished. I have not been able to distinguish any other differentiated viscus in any of the specimens which have come under my observation, and, certainly, nothing suggestive f differentiation of sex.

By the time that the larval filariæ have attained to this degree of development, the mosquito will possibly have already deposited its ova, and its own cycle will have been nearly completed. With the intention of following out the development still further, I have frequently kept insects until this stage was reached before examination, but all the attempts have proved fruitless, notwithstanding that the mosquito has been seen to go through its ordinary course of depositing its ova on the surface of water, and then perishing itself. Either no filariæ were found in its body, or if present they were dead, and careful examination of the water invariably yielded negative results in my hands. It would seem that the larvæ had perished. As the quantity of water used was so small, it is hardly possible, had filariæ in any stage of growth been present, that they could have so completely escaped observation. Possibly the more or less artificial conditions necessarily associated with the conduct of such experiments may account for these negative results. In the meantime I cannot, as a result of personal

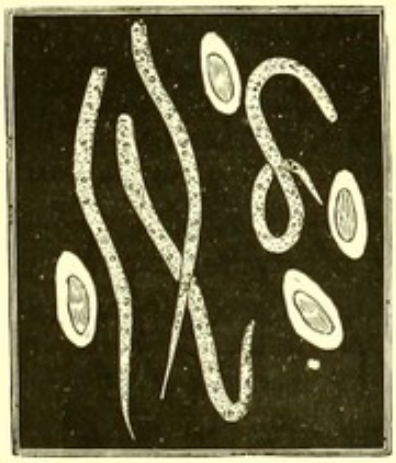


Fig. 62 . . . × 500 diam.

Embryos of a nematoid helminth from a bird, obtained in the stomach of a mosquito. A few blood-corpuscles are included in the sketch.

observation, affirm that a sojourn in the body of the mosquito, and subsequent transference to water, suffice to bring the *Filaria sanguinis-hominis* to maturity.*

A few words may be said regarding other hæmatozoic parasites which appear to find their way into the bodies of mosquitoes. In the first place, it may be mentioned that *dogs* appear to furnish a certain proportion, as I have repeatedly found filariæ in these insects in which not the slightest trace of the enveloping cyst, which characterises the human hæmatozoon, could be detected. Unfortunately the corpuscles of the dog's blood are so like those of man, as to size and appearance, that it is not possible to distinguish them with certainty, so that the examination of the fluid contents of the mosquito's stomach does not tend to throw any light on the source of the hæmatozoa in this instance. It is probable that other animals also contribute towards rendering the diagnosis more difficult.

* [See on the characters of the true "filaria-nursing" mosquito as got from Amoy. "*Observations on Filaria sanguinis-hominis in South Formosa*," by W. Wykeham Myers, M.B., Surgeon to "David Manson Memorial Hospital," Customs' Report, Shanghai, 1886.]

It is not uncommon, for example, to find the blood-corpuscles of *birds* forming a portion of the contents of the mosquito's stomach, and I have on several occasions observed extremely small embryo-nematodes associated with such corpuscles. Some of these are represented in the wood-cut on previous page (Fig. 62). If these helminths be compared with the figure given of the hæmatozoon of the crow (Fig. 59, page 613), they will be found to bear a close resemblance to it. It is very possible that these embryos may not have been derived from the crow, but there can be but little doubt, judging from the character of the red blood-corpuscles, that they had been derived from some bird. Facts of this kind also tend to add to the difficulty of ascertaining precisely the various developmental processes which any particular species of hæmatozoon undergo.

E.—The Mature form of Filaria sanguinis-hominis.

A letter appeared in *The Lancet* of 14th July, 1877, from Dr. Cobbold, announcing the discovery by Dr. Bancroft, of Brisbane, Australia, of what were believed to be cimens of the mature *Filaria sanguinis*. They had been found on two occasions: on the first, a dead specimen was found in a lymphatic abscess of the arm; and the second time four living specimens were obtained whilst tapping a hydrocele of the spermatic cord. Regarding these Dr. Bancroft had written the following description: "The worm is about the thickness of a human hair, and is from 3 to 4 inches long. By two loops from the centre of the body it emits the filariæ described by Carter in immense numbers."

During the last six years I have taken considerable interest in questions of this nature, and have, through the kindness of professional friends in India, had frequent opportunities of searching for the parental form of the *Filaria sanguinis-hominis*, but only succeeded in obtaining it on one occasion. This was a little more than a year ago—7th August, 1877. Descriptions of the specimens were published at the time,* but, in a paper dealing with the organisms of the blood, a brief account of these particulars should find a place.

For the opportunity of examining the particular case in which the filariæ were found, I am indebted to the kindness of the late Dr. Gayer. The patient was a young Bengalee affected with well-marked nævoid elephantiasis of the scrotum, associated with the presence of embryo-filariæ in the blood. The tumor and the sanguineous exudation which escaped on its removal were collected, and submitted to careful examination, and after a continuous search of eight hours, the long-sought-for helminth was eventually obtained. The specimens were, however, so greatly mangled by the needles used in teasing a clot under a dissecting microscope, that the description of the parental forms cannot at present be so complete as desired.

The specimens consisted of portions of two worms, male and female (Plate XLII, Figs. 1 to 4); the former, however, had unfortunately been torn across at two places, and the terminal ends could not be discovered. Both specimens manifested very lively

* *Indian Medical Gazette*, 1st September, 1877; *The Lancet*, 29th September, 1877, page 453; *Centralblatt für die medicinische Wissenschaften*, No. 43, 1877, page 770.

movements, notwithstanding their mangled condition. They were of a white colour, the cuticle was smooth and devoid of tranverse markings except such as were due to the contraction of the subjacent muscular walls.

The fragment of the male specimen which was found measured half an inch in length, and $\frac{1}{180}$ of an inch (·14 mm.) transversely; it was thinner than the female, but of considerably firmer texture,—so firm, indeed, that whilst endeavouring to make out its anatomy a considerable portion of it was lost by one of the needles used for dissecting, snapping and carrying a portion of worm along with it. On tearing the helminth across, the severed surface does not present a ragged edge, but an even outline (Fig. 4, Plate XLII). The male manifested also great tendency to coil, and it was only with difficulty that it could be separated from the specimen of the female parasite, around a portion of which it had twisted itself. It is unfortunate that its caudal end especially could not be found, as the definite decision of the genus to which it should be referred depends in a great measure on the characters which the posterior end of the male worm presents. The intestinal canal measured $\frac{1}{633}''$ (·039 mm.) across, and the sperm tube $\frac{1}{1500}''$ (·016 mm.).

The caudal end of the female worm also had been severed and could not be found; this, however, is of less moment. The length of the portion of the helminth secured was $1\frac{1}{2}$ inches, and its greatest width about $\frac{1}{100}$ inch. It was packed with ova and embryos in various stages of development; the latter, especially those of them which were mature, manifested active movements. The head is slightly club-shaped; the mouth does not manifest any very distinctly marked labial subdivisions, nor are there any chitinous processes evident either before or after death. The œsophagus is faintly striated and shades off imperceptibly into the intestinal tube, the latter being filled with moleculo-granular matter.*

The following measurements may be useful to future observers:—

Oral aperture to end of œsophagus	$\frac{1}{65}$ of an inch, or	·45 mm.
Diameter of oral aperture	$\frac{1}{3000}$ " " "	·008 "
Width of extreme end (anterior)	$\frac{1}{517}$ " " "	·047 "
Ditto anterior end at "neck"	$\frac{1}{545}$ " " "	·045 "
Ditto opposite junction of intestine with œsophagus	$\frac{1}{222}$ " " "	·112 "
Ditto about $\frac{1}{4}$ inch from anterior end	$\frac{1}{153}$ " " "	·162 "
Width where packed with ova and embryos	$\frac{1}{100}$ " " "	·25 "
Width of uterine tube filled with ova	$\frac{1}{222}$ " " "	·112 "
Ditto alimentary tube	$\frac{1}{666}$ " " "	·037 "

The ova do not possess any distinctly marked "shell;" from the smallest to the largest nothing but a delicate pellicle can be distinguished as enveloping the embryo in all its stages; consequently the form assumed by the ovum depends to a great extent on the degree of the surrounding pressure. In Fig. 3 (Plate XLII) ova of various shapes are depicted (spherical, triangular, oval), and with a considerable latitude as to size. The average of six measurements of the less advanced kinds of ova, *i.e.*, those in which the outline of the embyro was not distinctly evident = $\frac{1}{1304}''$ (·018 mm.) by

* A micro-photograph of this specimen is reproduced at Fig. 5, Plate XLIII.

$\frac{1}{2000}$″ (·012 mm.); whilst the average measurements of three ova in which the embyros were visible = $\frac{1}{666}$″ (·037 mm.) by $\frac{1}{790}$″ (·030 mm.).

When the latter, after having arrived at this stage of development, are examined during life, it is in many instances difficult to state whether they are to be considered as freed embryos or not, as the "egg-shell" has become so extremely attenuated and translucent as only with difficulty to be distinguished. By pressing the covering glass firmly the sac may often be ruptured. It, however, appears probable that, even when the embryo acquires worm-like appearances, the envelope is not lost in this species so long as it continues in the blood.

It is of importance to bear this in mind, as, contrary to what is seen with regard to the nematoid hæmatozoa of dogs, the embryos in the blood of man are each contained in a translucent cæcal tube. This tube is readily recognisable during life whenever the embryos can be properly observed in fresh clear serum, as also in spirit-preserved preparations. I possess at the present time specimens thus preserved of both species, one being contained in blood removed from the heart of a person who, during life, was known to harbour hæmatozoa, and the other obtained from the blood-vessels of a dog similarly affected. In not a single instance have I been able to distinguish the least trace of an enveloping tube in the latter, whereas in the former this tube can be clearly demonstrated in the majority of instances. Hence, notwithstanding their almost complete accord as to dimensions, the character just referred to is sufficient to distinguish slides prepared from either of these two specimens. A like distinction has been ascertained to exist between the two kinds of embryo-filariæ in China by Dr. Manson; but, according to Dr. Sonsino, those of Egypt, and apparently those of the Brazils, do not present this distinguishing feature. As may be recollected, it was mentioned that a distinction also exists between the disease with which the human hæmatozoon is associated in the different countries,—not a great difference certainly, but, nevertheless, one which should be borne in mind when deciding as to specific distinctions between the parasites.

It must also not be forgotten that the inhabitants of Brazil and of certain parts of Africa are, as has been known for at least a century, peculiarly liable to be the hosts of tissue-parasites. The minute thread-like sub-conjunctival filaria (*Filaria loa*), for example, though from two to six inches in length, has never been accurately described, and its precise thickness is not known yet, although it was discovered by Bajon so long ago as 1768,* and has since been frequently observed beneath the skin and conjunctiva of negroes and other persons. M. Guyon brought it before the notice of the French Academy in 1838, and again in 1864. On the former occasion, the specimens measured 30—40 mm., but the helminth described in 1864 was 150 mm. in length. It is not quite clear that they belonged to the same species. It is not impossible that the embryos discovered by Dr. O'Neill † in a disease of the skin

* *Comptes Rendus*, t. lix, 1864, p. 745.
† *The Lancet*, Feb. 10, 1875, p. 265.

termed *Craw-craw*, on the west coast of Africa, may prove to have been the offspring of some such helminth.

Again, the minute, thread-like nematoid described in America by Leidy, five inches in length and $\frac{1}{86}$ inch in greatest breadth, is not to be overlooked. It was obtained from the mouth of a child, and derives its name—*Filaria hominis-oris* *—from this circumstance.

All these circumstances point to the necessity of exercising considerable caution in arriving at any decision as to the precise relation of any of these as yet obscure parasites.

With regard to the helminths discovered by Dr. Bancroft in Australia, I am not in a position to offer an opinion. It has not yet been shown that they are blood-worms in the ordinary sense of the term, nor is it known that the individual from whom they were obtained harboured embryo-hæmatozoa. It is further to be remarked that the affections under which the persons laboured from which they were derived were not characteristic of the diseases with which these hæmatozoa have hitherto been known to be associated; indeed, it would appear that one of the principal morbid conditions with which they are associated in this country [India]—nævoid elephantiasis—is unknown in Australia. It may also be noteworthy that no male worm was found among the specimens.

Dr. Cobbold is, however, of opinion that they are identical, and it would be superfluous to say that the opinion of one who has devoted so many years to the study of helminths is entitled to consideration. This observer has lately (*The Lancet*, July 13, 1878) given a summary of the bibliography, etc., of these questions, in which I observe a slight error. It is with reference to the mature nematoid helminths found in Australia. These, Dr. Cobbold states, were "first discovered by Dr. Bancroft and first described by myself." It seems to me, however, that not only did Dr. Bancroft discover the parasite, but also furnished the first account of them which appeared. It is possible that the description supplied by Dr. Bancroft, which is quoted on a previous page, is not considered sufficiently precise to be accepted as such, from a naturalist's point of view. Allowing this, if, as Dr. Cobbold maintains, the Australian and Indian parasites are identical, the first full account of the mature *Filaria sanguinis-hominis*, as found in India, was published, both in this country and in London, previous to the appearance of Dr. Cobbold's description—having, indeed, been in the printer's hands before Dr. Cobbold had even seen the Australian parasites. Dr. Cobbold, moreover, refers to such prior publication in the appendix to his own article.

This trifling oversight will, I have no doubt, be duly corrected should this distinguished observer have occasion to write regarding these subjects in the future.

In considering the question of the relation which may exist between the presence of organisms in the circulation and disease, the conclusion is forced upon us that in reality but little of a definite character is known. One thing, however, is clearly

* *Proceedings of the Academy of Natural Science*, Philadelphia, vol. v., 1850-51.

manifest, that the supposition that beings become asphyxiated as a result of the existence of living organisms in the blood, is untenable. The study of their natural history as they occur in man or animals does not afford the slightest support to such a view. Indeed, so far as we at present know, it would seem that the presence of embryos in the blood, no matter how numerous, exercises no marked deleterious effect on the organism. It is probable, however, that the parents of these organisms, especially when helminthic, do exert a deleterious influence on the well-being of their hosts,—as, for example, the lesions which exist in the walls of the blood-vessels caused by the *Filaria sanguinolenta*, would seem to indicate. With regard to allied conditions in man, it is to be inferred that the influence exerted by nematoid embryos in inducing disease is apt to be overrated, as it would seem that the parasites may sojourn for long periods in the system without inflicting obvious injury. That certain injuries are effected, however, cannot well be doubted, but judging from what we know of the like condition in animals, the injuries result, not from direct action of living organisms on the blood-current in which they dwell, but from their action on some of the delicate tissues through which the blood circulates—such injurious influence being probably exerted more especially during the migrations of the parents of future embryo-hæmatozoa.

As it cannot be said that the vegetable organisms which may be found in the blood undergo any such transformations, the injury which their presence is supposed to occasion must be due to some other influence. What this may be it is difficult to conceive: the ordinary explanation that they consume the oxygen which is required by the blood itself cannot be regarded as sufficient.

CALCUTTA,
August 1878.

ADDENDUM.

Since the foregoing was written it has been found practicable to furnish facsimile reproductions of a few of the micro-photographs referred to in the text. They have been reproduced as permanent photographs by the Autotype Company.

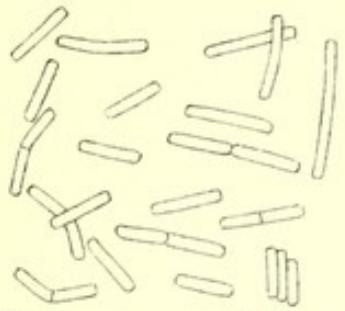


Fig: 1.....×1100

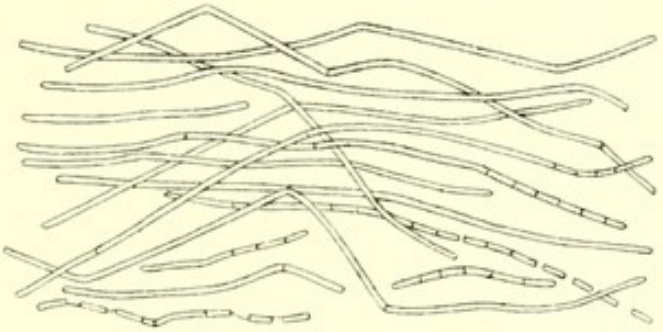


Fig: 2.....×600

Fig: 3.....×600

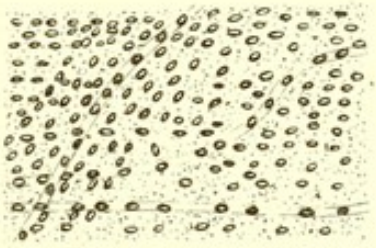


Fig: 4.....×600

Fig: 5....×1000[*a*, *b* × 2000]

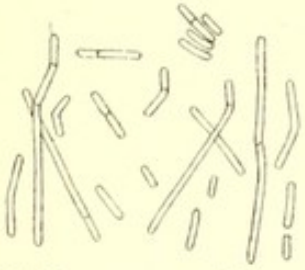


Fig: 6.....×1000

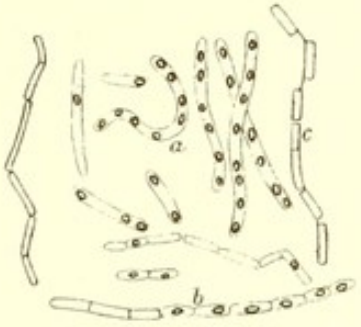


Fig: 7.....×1000

Fig: 8.....×1000

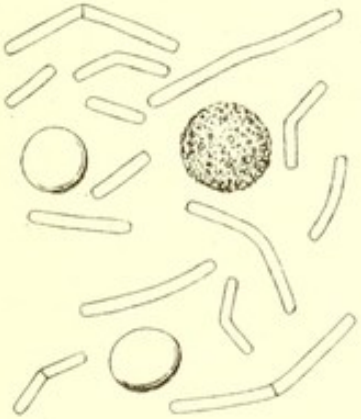


Fig: 9.....×1000

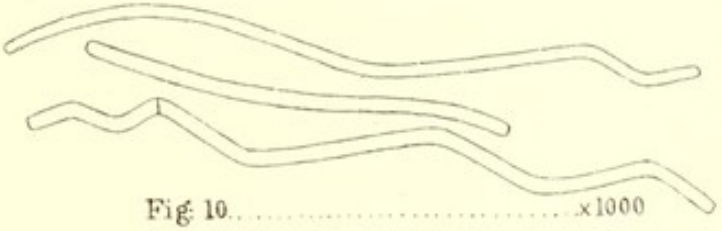


Fig: 10.....×1000

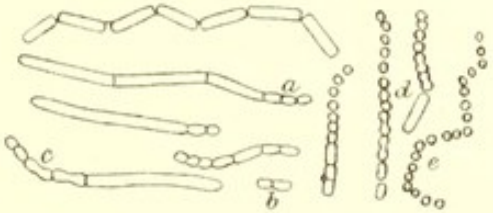


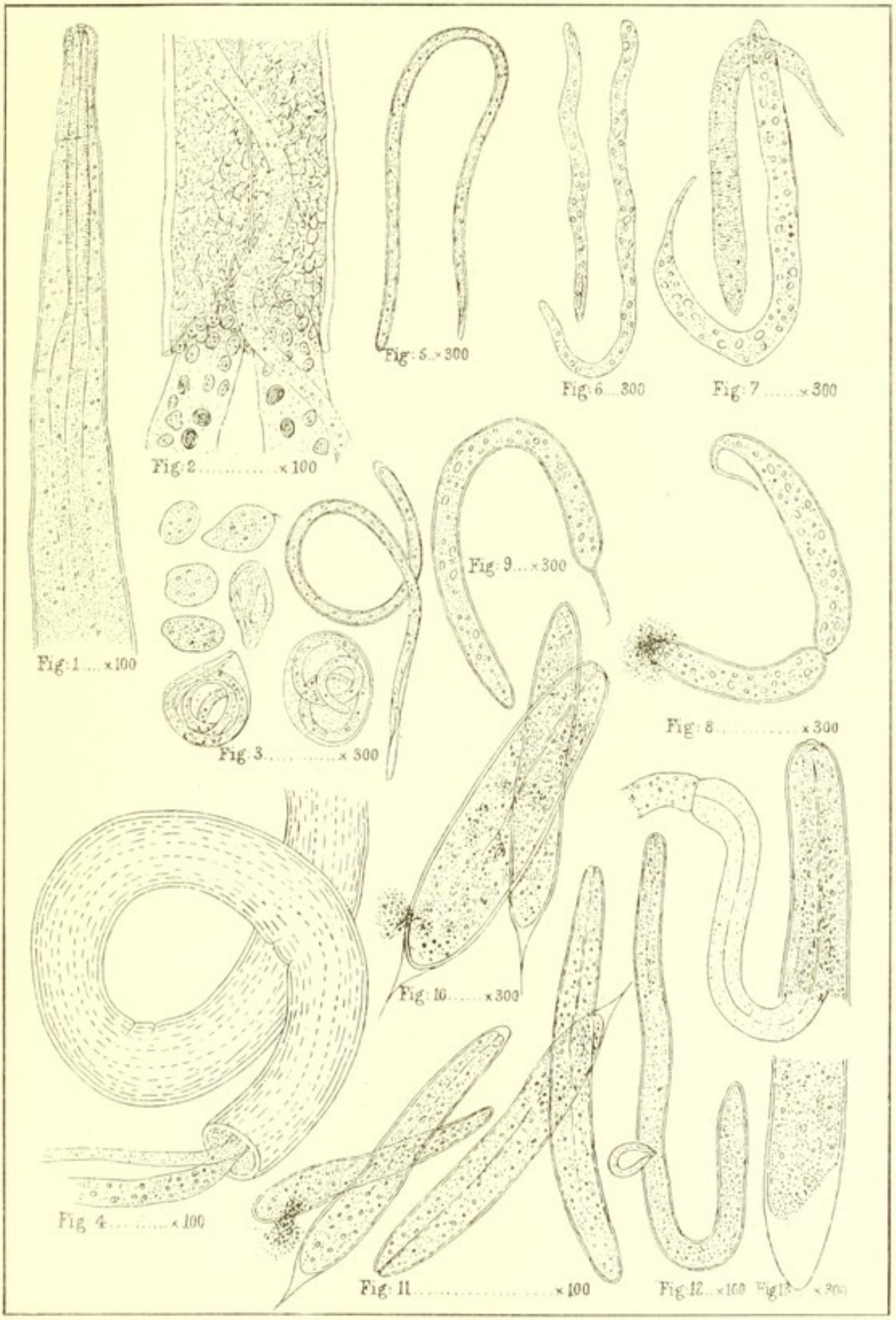
Fig: 11.....×1000

Fig: 12....×1000

T. R. Lewis, ad nat. del.

To face p. 658.

DEVELOPMENTAL STAGES OF ORGANISMS FOUND IN THE BLOOD OF HEALTHY ANIMALS SHORTLY AFTER DEATH.



T. R. Lewis ad nat. del.

To follow Plate XLI.

FILARIA SANGUINIS-HOMINIS: { FIGS. 1–4 Mature form [♂ and ♀], Embryos, and Ova
,, 5–13 Changes undergone by Embryos in CULEX MOSQUITO.

Figs 1 & 2.
Flagellated Organisms.
in the Blood of Rats.

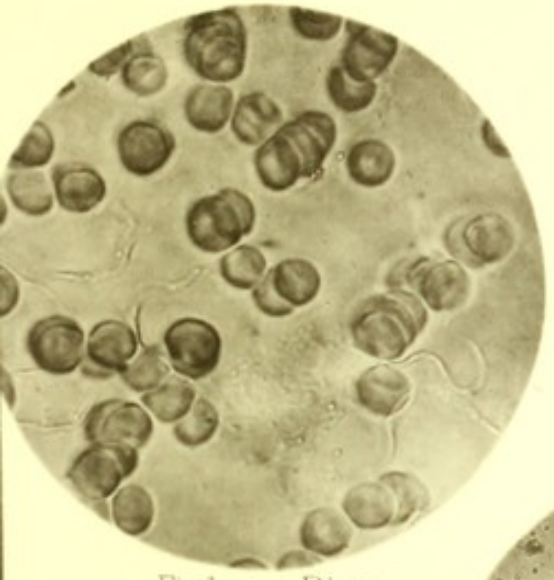


Fig.1,×700 Diam.
[Osmic acid-preparation.]

Fig.2,× 700 Diam.
[Dried preparation]

Fig 5,×25 Diam.
Filaria.
sanguinis-hominis.
[mature form.]

Fig.3,×700 Diam.

Figs.3 & 4.
Spirilla in the Blood of
Fever Patients.

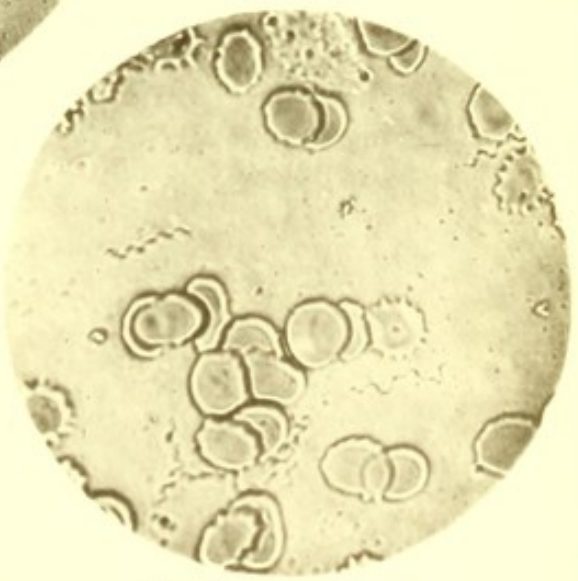


Fig 4 × 700 Diam.

Lewis fecit.

Autotype Compt

Micro-Photographs of various Organisms in the Blood.

PLATE XLI.

Illustrating the developmental stages of organisms found in the blood of healthy animals shortly after death :—

FIG. 1.—A tracing of bacilli from a micro-photograph. Magnified 1,100 diameters.
„ 2.—Growth of ditto into long filaments. Magnified 600 diameters.
„ 3.—Formation of "spores" in ditto.
„ 4.—The filaments having become nearly invisible, the "spores" only are seen, arranged linearly. Magnified 600 diameters.
„ 5.—Isolated "spores" in the condition sometimes described as "germinating." Magnified 1,000 diameters (Fig. *a*, *b*, magnified 2,000 diameters).
„ 6 to 8.—The developmental stages of a bacillus *below* the average dimensions. Magnified 1,000 diameters.
„ 9.—Bacilli *above* the average dimensions. Magnified 1,000 diameters.
„ 10.—Ditto showing growth into filaments. Magnified 1,000 diameters.
„ 11.—Ditto subsequently undergoing fission. Magnified 1,000 diameters.
„ 12.—Spore-like bodies which formed in a portion of the filaments delineated at Fig. 10. Magnified 1,000 diameters.

PLATE XLII.

Illustrating the mature Filaria sanguinis-hominis, ♂ and ♀, and some of the developmental stages of the Embryos :—

Fig. 1.—Anterior portion of mature helminth. Magnified 100 diameters.
„ 2.—Middle portion of parasite showing alimentary canal ; and the uterine tubules filled with ova. Magnified 100 diameters.
„ 3.—Ova and embryos. Magnified 300 diameters.
„ 4.—A portion of the male worm, with alimentary and sperm tubules escaping at one of the torn ends. Magnified 100 diameters.
„ 5.—Embryo recently ingested by a mosquito. Magnified 300 diameters.
FIGS. 6 & 7.—Early changes undergone by the embryos in the mosquito.
FIG. 8.—?
„ 9.—More advanced stage of the development of the embryo. Magnified 300 diameters.
„ 10.—The "sausage-form" stage of development of the embryos. Magnified 300 diameters.
„ 11.—The embryos acquire more worm-like proportions. Magnified 100 diameters.
„ 12.—A still further advanced stage : the alimentary canal distinguishable. Magnified 100 diameters.
„ 13.—Ditto : more highly magnified (300 diameters). The re-agent applied had caused the contents of the caudal end to contract.

PLATE XLIII.

Micro-photographs of various organisms in the blood :—

FIG. 1.—Flagellated organisms in the blood of healthy rats. A thin layer of blood, having been spread over a cover-glass, was exposed to the fumes of osmic acid and subsequently mounted as a dry preparation in the ordinary manner. It was then photographed as seen under a Ross's $\frac{1}{12}$" immersion objective. (*Vide* Part II, A.) Magnified 700 diameters.

FIG. 2.—A preparation of the same blood as in Fig. 1. Instead, however, of exposing it to the influence of osmic acid, it was allowed to dry spontaneously. When dry the preparation was stained by means of a weak solution of aniline-blue and photographed as seen under a $\frac{1}{12}$" objective. (*Vide* Part II, A.) Magnified 700 diameters.

FIGS. 3 & 4.—Spirilla in the blood of fever-patients at Bombay—two micro-photographs of osmic acid preparations, mounted dry. Many of the red blood-corpuscles are seen to present irregular margins in both figures. A white amœboid corpuscle is visible towards the upper edge of Fig. 4. (*Vide* Part I, G.) Magnified 700 diameters.

FIG. 5.—Anterior portion of the mature *Filaria sanguinis-hominis*, photographed under a Ross's 3" object glass. The width of the worm is slightly increased owing to the pressure exerted by the cover-glass. (*Vide* Part II, E.) Magnified 25 diameters.

FURTHER OBSERVATIONS
ON
FLAGELLATED ORGANISMS
IN THE
BLOOD OF ANIMALS.

BY

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1884.

IN a memoir on "The Microscopic Organisms found in the Blood of Man and Animals," published in the "Fourteenth Annual Report of the Sanitary Commissioner with the Government of India," and which was, in great part, reproduced in the first three numbers of the *Quarterly Journal of Microscopical Science* for January 1879, a chapter was devoted to a description of certain flagellated organisms which I had found in the blood of rats. This chapter will be found at p. 604 of this volume, so that it will not be necessary to do more than very briefly recapitulate what was given therein.

Having been directed to make certain inquiries regarding the nature of the sometimes designated, "spirillum-fever" which prevailed in Bombay during the earlier part of 1877, I had occasion to examine the blood of a considerable number of animals, and in July of that year detected spirillum-like organisms in the blood of healthy rats. In some instances these were so numerous that the blood when examined under a high power seemed to quiver with life. On careful focussing it was ascertained that each organism consisted of a body-portion and of an extension of it in the form of a gradually tapering, long flagellum, the former average 25μ in length by 1μ in width, whilst the flagellum brought up the total length of the organism to about 50μ or longer, for it was by no means certain that the whole length of the free end of the flagellum was visible. They were found not to be very sensitive to reagents, as they continued, for example, to manifest lively movements in a weak solution of bichloride of mercury for eight hours, and an exposure of several minutes to chloroform vapour did not seem to affect them. A weak solution of ammonia did not affect them for some time, but a stronger solution of potash affected them at once. When a drop of blood containing them was placed on a slide arranged for the

application of electricity, it was found that an interrupted current of such a strength as could not be comfortably borne by an individual was tolerated by these beings for several consecutive hours.

They were found in two species of rats—*Mus decumanus* and *Mus rufescens*—and in 29 per cent. of the animals examined. At that time I had not specially searched for these organisms anywhere except in Calcutta, nor had I found them in the blood of any animal except in that of the rat. I have since found them in rats at Simla, in the Himalayas, at an elevation of 7,500 feet above sea-level, though as regards the blood of mice and of musk rats I have searched for them in vain both in Simla and Calcutta.

That they are, however, to be found in the blood of other animals has been demonstrated by Dr. Griffith Evans, the present chief of the veterinary department in Madras, who, in 1880, whilst examining the blood of horses suffering from a wasting form of disease termed "surra" in the Punjab, found that it frequently swarmed with organisms of this character. Dr. Evans further made the very interesting observation that in the blood of a couple of camels, suffering apparently from a disease allied to surra in the horse, flagellated organisms were present in one, and nematoid embryos, closely resembling those which I described some years ago as being found in the blood of man, the *Filaria sanguinis hominis*,* in the other. I have elsewhere† drawn attention to this parasite of the camel (parents and embryos), and suggested that it might be called *Filaria Evansi*. I hope, however, to describe it at greater length in the next number of the *Quarterly Journal of Microscopical Science*.

With the view of ascertaining whether these flagellated organisms could be transferred to other animals, Dr. Evans had injected some blood from a horse, in which these organisms abounded, into the subcutaneous tissue of a dog and of a bitch, and on examining their blood four or five days afterwards precisely similar organisms were found in the blood of the bitch, but not in that of the dog. This bitch had a suckling puppy about a couple of months old, and its blood also contained these organisms, although it had not been intentionally inoculated; but as regards the possibility of the puppy having likewise been inoculated from the horse it is to be mentioned that a little of the blood was given to the bitch to eat, and it is quite possible that the puppy likewise consumed some of this. Unfortunately, the blood of these animals had not been examined as a preliminary procedure, so that it cannot be definitely declared that the organisms had been derived from the blood of the horse. It is just possible that they may have existed in their blood previously, and, in this connection, it is to be borne in mind that as regards rats, attention was drawn in my previous article to the circumstance that the blood of those caught in

* "On a Hæmatozoon in Human Blood; Its relation to Chyluria and other Diseases." Calcutta: Office of Superintendent of Government Printing, 1872, and page 503 of this volume.

† "Proceedings of the Asiatic Society of Bengal," March 1882.

a particular room would be affected, "whereas the blood of rats in another part of the building would not contain them. The servants had ultimately come to recognise this, as, whenever they learnt that a particular rat's blood contained the desired organisms, they diligently endeavoured to secure the rest of the family," so that the possibility is not absolutely excluded that the finding of these parasites in the blood of the puppy and of its mother may have been a coincidence and not the direct result of the experiment; nor is it known to what extent the blood of horses and camels or other animals in this part of India [Madras] may harbour these organisms or may have harboured them at that time.

These flagellated blood-parasites are not, however, limited to India, for in 1881 Wittich described similar organisms in the blood of hamsters in Germany.* Wittich's experience coincided with my own as regards their being found in the blood of apparently perfectly healthy animals, though Dr. Robert Koch,† instigated by the result of Wittich's observations, found that the hamsters which he procured died, one within two days of being in captivity, and four others subsequently. It does not appear that the blood of these hamsters was examined during life, but after death it was found, in each case, to contain the organisms in question. No reference is made to the examination of other hamsters, so that it is not quite clear whether the animals died as a result of captivity or in consequence of the parasitism. As regards rats thus affected I have had them kept in a cage for weeks, and to all appearances in a state of perfect health. Both Wittich and Koch suggest that the parasites found by them in the blood of hamsters are in all probability identical with those found by me in rats in India; and Koch gives two micro-photographs of them which correspond very closely with the micro-photographs which were published by me in the previously mentioned Indian "Sanitary Report."

What these organisms are and whence their origin is by no means clear, and as the suggestions which have been offered by various authorities regarding these points are so greatly at variance it seems highly desirable that every detail which can be collected concerning them should be placed on record. This is all the more to be desired, seeing that the question has arisen of their possible influence as a cause of disease.

I had every opportunity of satisfying myself that the parasite found by Dr. Evans in the dog is identical with that in the rat, as Dr. Evans brought the puppy to Simla in October, 1880, and very kindly made it over to me for observation. The accompanying sketch represents some of the forms assumed by these organisms as observed under a Prazomwski's 1·5 mm. immersion objective. This, together with the following remark, made at the time, are copied from my note-book:—

A drop of blood having been obtained from the puppy's ear about 9 a.m. on the 26th October, it was found to contain a considerable number of these organisms in a

* Centralblatt für die medicin. Wissensch., vol. xix, No. 4.

† "Mittheilungen aus dem Kaiserlichen Gesundheitsamte," vol. i, p. 9, 1881.

state of great activity. Their movements were so rapid that it was impossible to obtain a clear conception of their exact form. The slide was set aside and again examined at 4 p.m., when it was found that their movements were much more languid and less suggestive of spirilla than they were in the morning. It was at this time that the figures here reproduced were sketched. As the rapidity of the movements diminished there appeared to be a greater tendency to throw out flagellæ, and wave-like extensions of their substance seemed to originate at the thicker end and to pass along rapidly towards the flagellum. The plasma-substance appeared to be contractile along the whole length of the parasite, even to the very tip of the flagellum, and, frequently, an impression was conveyed, suggestive of the organism being flat or ribbon-like; consequently, when seen in profile they presented a much more attenuated aspect than under other conditions. Moreover, it is difficult to decide how much of the wave-like appearance above referred to is due to rapid

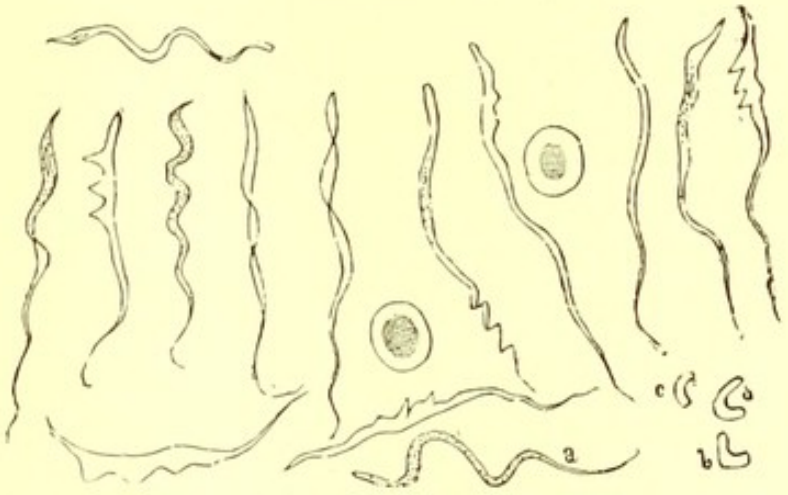

Fig. 63.—Various appearances presented by flagellated organisms in blood from a puppy's ear, seven to eight hours after it had been under the cover-glass: at *a* after eleven hours. *b*, *c*, *d*, changes undergone by a protoplasmic body in the field during the course of a few minutes. Two blood-corpuscles introduced to indicate the relative size. × 1000 diameters.

lateral prolongations of the protoplasm, and how much to the aspect which would be presented when this ribbon-like form undergoes rapid spiral contractions. In the above figure (63) an attempt has been made to reproduce the most striking of these different appearances, and a couple of red blood-corpuscles have been introduced to indicate the relative size under the same magnifying power.

At 5 p.m. the organisms manifested signs of losing vitality, became more ribbon-like and pointed,—almost, if not quite, "lashed," at the thicker end also; moreover, a clear space is observed at a distance of from 2 to 3 μ from the point highly suggestive of a vacuole. This is indicated in two or three of the figures. They averaged about 30 μ in length and from 1 to 2 μ in width at the thickest part.

At 8 p.m. only two specimens could be detected in the slide, one quite motionless, the other nearly so. One of these is carefully sketched at *a* in the

woodcut (63); a vacuole-like spot is observable at one part, and the parasite is granular almost along its entire length. Near this specimen a curved protoplasmic object was observed to alter its form very slowly, as shown at *a*, *b*, *c*. Its further changes could not be followed, as it was lost whilst its form was being outlined, but I have on two or three occasions observed objects of this character associated with these parasites, and sometimes think that they must represent either an earlier or a later stage of them than is ordinarily seen.

Further specimens of blood were obtained from the puppy on the 29th and 30th of October, but no organisms could be detected; on the 3rd November, however, it is noted that the organisms were very numerous in the blood, and that "the dog looks remarkably well."

Shortly afterwards the puppy was taken to Calcutta, and when examined on the 25th November no organisms could be detected in its blood. On the 3rd December,

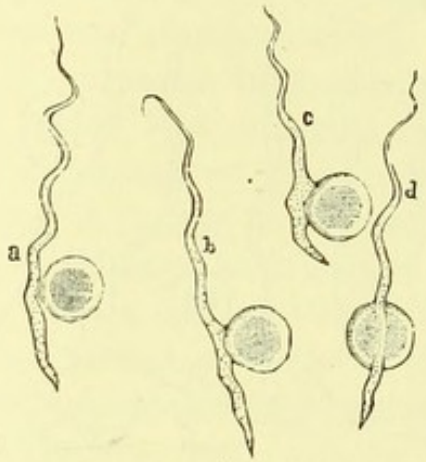

Fig. 64.—*a*—*d* appearances presented by one of the flagellated organisms which had applied itself to a red blood-corpuscle. × 1000 diameters.

however, they were readily found. A specimen which was observed on this occasion may serve to illustrate a phenomenon which I have frequently observed in connection with like organisms in the rat. A slide of blood which had been kept in a moist chamber for twenty-four hours having been placed under the microscope, the eye was attracted by the way in which one of the parasites appeared to play with a red blood-corpuscle. It was watched for fully an hour, until, in fact, the field was disturbed by the evaporation along the edge of the cover-glass. Its movements were sluggish and just sufficient to slightly shift the corpuscle. It had not attached itself to the corpuscle by either of its ends, but at a spot about 8 μ from the point of the thicker end as shown in Fig. 64, *a* to *d*. Sometimes there appeared to be a slight interval between the corpuscle and the parasite (Fig. 64, *a*), and occasionally even a greater interval than is indicated in the woodcut, but both parasite and corpuscle, nevertheless, continued to move in unison, as though some filamentous connection existed between them, which, however, was too delicate

to be distinguished by the highest power which I possessed. At other times the organism appeared to be closely applied to the corpuscle, as though the latter were being embraced by two short lateral pseudopods, and the outline of the corpuscle appeared as if squeezed (Fig. 64, *b*, *c*). At Fig. 64, *d*, the corpuscle is shown with the parasite immediately below it. No distinct flagellum could be detected extending from the thicker portion of the parasite, though it was frequently observed to present a ribbon-like appearance.

Shortly after this the puppy got the "distemper," and was struck by one of the native servants, so that it lost the sight of the right eye. On the 15th January, 1881, several specimens of blood from its ear were examined, but not a single parasite could be detected. Further examinations were made on the 12th and 28th February, and again on the 24th March, but not a single specimen was found. The dates have been carefully recorded, as they may be of use to future observers; and the notes of observations in this instance have been made to subserve the double object of illustrating the more salient points in the microscopy of the parasite, and to give the exact history of this form of parasitism in the dog during a period of from four to five months.

There are, however, a few other points in connection with the microscopy of these organisms which it seems desirable to refer to as they may be of assistance to systematic writers in deciding their precise position in the animal (or, as some authorities may perhaps consider, vegetable) kingdom

These supplementary details will be based on further observations which have been made from time to time, as opportunities offered, during the last three or four years, on the blood of rats, but more particularly on a series which were conducted for purposes of comparison whilst the organisms in the dog were being watched.

On January 30th, 1881, the following entry is made in my note-book: Examined the blood of five rats, aud found flagellated organisms in two of them. One of the latter was a pregnant female, but this one, however, did not contain many specimens of the parasite, and none were found in the blood of its young. The blood of the other rat swarmed with the organisms.

As it had been found that the parasites were remarkably well preserved in a 0·75 per cent. solution of salt and water, half a Pravaz-syringeful of a mixture of the blood of this rat, and of the salt solution—one part to three—was injected into the sub-cutaneous tissue of the thigh of a healthy rat, free from blood organisms, and which had been under observation for a fortnight.

The animal did not appear to be materially affected by this procedure, and on February 12th it is recorded: "The rat continues to enjoy excellent health; eats and drinks freely. Not a trace of any organisms found in its blood, although the flagellated organisms which had been introduced into its tissues were found to be alive two days after the operation in what remained of the mixture which had been injected."

It would thus appear that these organisms are at all events not very readily transmissible by means of subcutaneous injection from one rat to another.

Nor have I succeeded in preserving them beyond two or three days outside the body. Attempts have been made to "cultivate" them in plain water, in sugar and water, glycerine and water, and in salt and water, as, also, in the blood itself, both with and without the aid of an incubator. But I could not satisfy myself that they multiplied; on the contrary, they seemed to degenerate after removal from the animal hour by hour. A weak solution of salt, as already observed, appeared to be a more favourable medium for retaining their vitality than any other which I have tried, and is a very convenient medium for studying the various stages of the disintegrative process. The different appearances which they presented as watched in such a solution are sketched at Fig. 65; from which it will be observed that the organisms present a striking resemblance to the more generally recognised forms of spermatozoa. On the

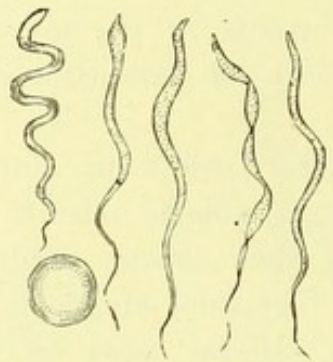

Fig. 65.—Flagellated organisms from the blood of a rat preserved in a 0·75 per cent. solution of common salt. × 1000 diameters.

third day the specimens figured were no longer recognisable in the fluid in which they were kept.

Whilst watching these particular specimens I was further able to satisfy myself that these, like the generality of flagellated organisms, moved with the lash in front—that is to say, in the direction indicated by the arrow which is placed alongside of the middle specimen in Fig. 66 on the opposite page. Since this period I have frequently observed the same thing in other specimens, though it is scarcely possible to be sure of the direction of the movement until after the parasite has become sluggish. Moreover, they may also be observed to move with the thicker end forwards, but only for short distances.

As already remarked, when describing the specimens from the blood of the dog, they seem to attach themselves to surrounding objects by means of some portion of the thicker end. The specimen sketched in the left half of Fig. 66 was observed to remain attached to a granular mass by the extreme point of its thicker end for a considerable time, whilst the remainder of the parasite was seen to swing freely from *a* to *b* and from *a* to *c*, the free end of the lash presenting a screw-like appearance. Another specimen was watched for half an hour whilst it remained attached to a granular

mass in the preparation, but in this instance, as represented at the right half of Fig. 66, the parasite had fixed itself at a point about 3 μ from the end, and to swing itself, as from *a* to *b*, from this fixed position. It will be noted that the part of the body by which the parasite attaches itself here corresponds with that represented as having been attached to the red blood-corpuscle in a previous figure. In this instance, also, the lash was observed to manifest incessant screw-like movements, the movement apparently commencing at the tip of the flagellum and proceeding rapidly upwards until the point of attachment to the granular mass was reached, and here it stopped abruptly.

Many attempts were made to demonstrate the presence of another flagellum at the opposite end, but without any satisfactory result. In preparations made by drying a film of the affected blood on a cover-glass both ends of the parasite are often seen to be very pointed, but in all cases a distinct flagellum could only be made out at

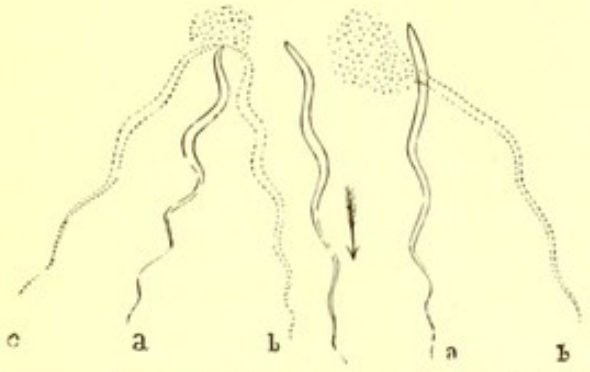

Fig. 66.—Different methods of attachment to foreign bodies observed in two specimens of the organisms from the blood of a rat. The arrow along the middle figure indicates the direction of progressive movement. × 1000 diameters.

Fig. 67.—Action of gentian-violet on specimens of the organisms from the blood of a rat. × 1000 diameters.

one end. When a solution of gentian-violet is added to such a slide the parasites are rapidly stained and present a granular appearance throughout, granules being frequently distinguishable as far as the extreme tip of the flagellum, as may be observed in Fig. 67. Occasionally the flagellum appears to be retracted, as shown in the sketch in the middle of the figure, and I have sometimes thought that such a retraction of the flagellum could be observed whilst the organism was in a condition of extreme activity. The specimens in this figure were carefully outlined to scale by means of the camera lucida.

I am wholly unable to suggest any explanation for the presence of these flagellated parasites in the blood of animals. It will be recollected that they have now been observed in the blood of the horse, camel, and hamster, in addition to that of the rat; and, further, that they have been found in the blood of two dogs, but whether as the result of intentional inoculation or otherwise must for the present be left undecided. As regards the season in which they may be detected, I find that there are entries in my note-book of their having been seen, at one time or another, in the blood of rats in nearly each month of the year.

For some time I was inclined to think that they might be the spermatozoa of some parasite hidden in the tissues of the animal, a view which strongly forced itself upon me some years ago, in 1878, by having accidentally observed a large number of spermatozoids escaping from the reproductive pore of a fragment of tænia which I had found while dissecting a rat. The "head" of the tænia was not found, so that the entozoon could not be identified with certainty, but it probably was a portion of Tænia microstoma or some closely allied species. My notes run as follows:—"The segments having been placed on a slide spermatozoids are seen to escape from the genital pore of nearly every one of them. For a few moments after their escape they presented, with amazing exactness, the characters of the spirillar organisms found in the blood of rats, but which were not present in the blood of this particular specimen. It seemed, however, that the water in which the tænia segments were mounted and into which they escaped was not suitable to their preservation. They rapidly underwent changes of form, and almost before half a dozen of them could be sketched disintegrative changes set in, and the previously active flagellated organisms were transformed into quiescent, filamentous shreds." It has not been considered necessary to reproduce the sketches of them which were made, seeing that both as to size and form they are so very like several of the figures in the woodcuts already given. The organisms found in the blood of rats, however, are by no means so sensitive to the action of water as this.

Leuckart, in his recently published review of the additions which have been made during 1876 to 1879 to the literature of low forms of animal life,* suggests that it is doubtful whether these rat organisms should not be relegated to the class of organisms described by Dr. Gaule as being present in the blood and spleen of frogs and termed by him "Cytozoa" rather than to the "Flagellata." Readers will recollect that Dr. Gaule was under the impression that these "Cytozoa" (also described by him as "Würmchen") were the result of certain changes which took place in the blood-corpuscles and other cellular elements of frogs. Professor Ray Lankester, however, in the number of the *Quarterly Journal of Microscopical Science* for January, 1882, has shown that such an inference is wholly erroneous, and has, I think, very satisfactorily demonstrated that Gaule's Cytozoa are "independent parasitic organisms"—that they represent, in fact, the young stage of a Sporozoon. It is not quite clear to which view of the nature of these "Cytozoa," to Gaule's or to Lankester's, Leuckart refers in the paragraph above cited.

In his recently completed "Manual of the Infusoria," Mr. Saville Kent, on the other hand, has placed the blood-organism of the rat amongst the Flagellata, and has named them Herpetomonas Lewisi; at the same time he points out that it is possible that further research "may possibly demonstrate their identity with the discharged spermatic elements of the minute nematodes, micro-filariæ, or other metazoic endo-parasitic forms known to flourish amid the same surroundings."

* "Bericht über die wissenschaftlichen Leistungen in der Naturgeschichte der niederen Thiere," II Hälfte 1883, p. 775.

PART IV.

A MEMORANDUM

ON THE

DIETARIES OF LABOURING PRISONERS

IN

INDIAN JAILS.

BY

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CHAPTER I.

A BRIEF SKETCH OF SOME RECENT RESEARCHES BEARING ON THE QUESTION OF LABOURING DIETARIES.

1. IN the following memorandum an attempt will be made to furnish an approximate estimate of the nutritive value of the several scales of diet for Native labouring prisoners which are at present, or have until recently been, in force in Indian jails. Before proceeding to do this, it will be necessary to refer to a few general principles which have to be clearly understood in order to render the remarks which will be made regarding the essential constituents of such dietaries more intelligible, without, however, entering into abstruse physiological details which would be out of place here. A mere tabular statement of the several ingredients constituting the diets in the several provinces would be of comparatively little value unless accompanied by a statement of their chemical composition; and, in order to judge of the comparative merits of dietaries so analysed, it is essential that a clear conception should be formed as to what particular portions are specially adapted to the nutrition of the body, and in what proportion they should be given so as to obtain the most favourable results.

2. As the body itself is composed of organic and inorganic substances, the food essential to its support must likewise consist of such substances. The *inorganic* portion of food consists of water and of various salts; and *organic* alimentary substances are those which have been produced under the influence of life, which may be either animal or vegetable. In reality, however, all organised food stuffs are

derived from the vegetable kingdom, seeing that, more or less directly, herbivorons animals constitute the prey of the carnivora. As organised food substances usually contain the requisite proportion of the unorganised, it seems unnecessary, in a note of this kind, to give in detail the amount of the inorganic constituents of individual diet scales.

3. It will, therefore, be necessary to consider specially the leading characteristics of organised food stuffs. These may be classified under two principal headings—those which contain nitrogen and those which do not. The nitrogenous group of compounds is very commonly referred to as *albuminates* [also *proteids*] from the circumstance that albumen forms the most important alimentary constituent of the group—a substance which is directly derivable both from animals and plants. The non-nitrogenous group is ordinarily sub-divided into (*a*) *carbo-hydrates*, the most important compounds of which are starch and sugar; (*b*) *fats*.

4. In the present memorandum the sum of the ingredients in all the principal scales of diet given in the text will be found resolved into these three great alimentary principles; but for the sake of conciseness, and as tending to simplicity of arrangement, the nutritive value of the individual ingredients given in the series of the appended dietary tables has been expressed in terms of nitrogen and carbon only. This does not imply that these two elements are assimilated when in an uncombined condition, but that the quantities of the special ingredients cited in any particular diet may, in the laboratory, be resolved into so many grains of nitrogen and carbon. Computations of the amount of these two elements in the different alimentary substances furnish a convenient and simple index of the approximate nutritive value of a combination of food stuffs, seeing that, as the late Dr. Parkes expressed it, "the phenomena of nutrition are chiefly owing to the various chemical interchanges of nitrogen and carbon (and in some instances of hydrogen with oxygen)."

5. Speaking generally, the chief functions of the nitrogenous principles of food seem to be the development and renovation of the tissues, and the acceleration of the chemical changes which take place in them; whilst the non-nitrogenous, or carbonaceous, material furnishes the principal source of mechanical force; or, as Pavy has it, the former may be spoken of as holding the position of the instrument of action, while the other supplies the motive power. The quantity and the proportions of these proximate alimentary substances which are required to maintain individuals in health, the particular part which each proximate aliment plays in the animal economy, and the relative proportions in which they should be given during periods of rest and of activity, are questions regarding which there is still far too much uncertainty to admit of any definite statement being made. Until recently, the view, advocated by Liebig, was generally held that physical exertion involved a positive waste of muscular tissue, and that, consequently, an increase of the "flesh-formers," as the albuminate constituents of the food were described, was required in proportion to the amount of mechanical labour which the body was called upon to undergo. As a result of this

teaching, the leading object which has been ordinarily kept in view in the construction of dietaries has been to increase the nitrogenous elements in the food proportionately, and this in a somewhat arbitrary fashion, to the amount of work exacted.

6. On the strength of this doctrine it has frequently been assumed that the working population of this country, and especially the rice-consuming portion of it, is under-fed, seeing that the amount of albuminous material which enters into their ordinary food is evidently far too small to compensate for the waste of the muscular tissue which the work they perform was supposed to entail. The great distance which a palanquin-bearer, for example, will often travel on food containing an extremely small proportion of nitrogenous material has astonished many European observers, the quantity of albuminates in his food being quite inadequate to replace the waste of muscle which, it was supposed, must have taken place in carrying himself and his burden. Every-day experience in this country, therefore, seemed to contradict the doctrine that physical labour and destruction of the nitrogenous muscular tissue should be looked upon as almost synonymous.

7. This experience is quite in accord with the teachings of the leading physiologists of the present day. In opposition to Liebig, who admitted that the heat but not the motion of the body was due to the oxidation of combustible matters, J. R. Mayer (so far back as 1845) maintained that the chemical force contained in the ingested food and in the inhaled oxygen was the source of the motion as well as of the heat. The truth of this statement has been confirmed by many observers, and during recent years Mayer's researches have been greatly extended. Conspicuous amongst these researches are the experiments which have been made on men and animals by Professors Pettenkofer and Voit, and which, amongst other things, have conclusively demonstrated that the amount of nitrogen excreted by the body during rest is so nearly the same as during exertion that the possibility of power being dependent on nitrogenous waste is, virtually, excluded. These observations, and many others of a like character,* have a very practical significance as regards the question of the most suitable dietary for a labouring population, and it would clearly be a mistake to continue formulating scales of diet based on a doctrine which is no longer tenable.

8. Indeed, the present tendency is to invert the doctrine of Liebig, and to hold that it is carbonaceous and not nitrogenous material which is chiefly consumed during mechanical action. In a recent lecture delivered before the British Association, Professor Burdon-Sanderson says:—"In what may be called 'commercial physiology,' the physiology of trade puffs, one still meets with the assumption that the material basis of muscular motion is nitrogenous; but by many methods of proof it has been shown that the true *Oel in der Flamme des Lebens* is not proteid [or albuminoid] substance but sugar or sugar-producing material."† Although, according to the most recent

* A very carefully prepared account of the principal of these will be found in Chapter IX of Gamgee's *Physiological Chemistry of the Animal Body*.—Vol. I, 1880.

† *Nature*, September 8th, 1881, page 440.

observations, it may not be strictly accurate to compare the relation of the food to the body with that of the fuel to the steam engine, still the modified form of the popular illustration which has been suggested by two prominent authorities on this subject—Professors Fick and Wislicenus—may serve to aid in rendering the subject more intelligible without being materially misleading as regards the more salient facts. A bundle of muscular fibres may be looked upon as a kind of machine, consisting of albuminous material, just as a steam engine is made of metal. Now, as in the steam engine coal is burnt in order to produce force, so in the muscular machine carbonaceous material is burnt for the same purpose. And in the same manner as the iron, etc., of which the engine is constructed is worn away and oxidised, so also is the constructive material of the muscle worn away. In a steam engine moderately fired and ready for use the oxidation of iron, etc., would go on tolerably equably and would not be much increased by the more rapid firing necessary for working, but much more coal would be burnt when it was at heavy work than when the work was only trifling.

9. As excessive work in the case of the engine implies a slight increase in the wear and tear of its constructive material, so it has been experimentally demonstrated that some slight increase also occurs in the expenditure of the albuminous structures of the body as well as of the carbonaceous elements of food during severe physical exercise, so that it would seem that something more than a preponderance of the non-nitrogenous principles is required to sustain the body under such conditions, and this conclusion, as Pavy expresses it, "corresponds with the promptings of our instinctive inclination."* But there can be little doubt that the extent of this instinctive inclination to have recourse to more albuminoid food on account of extra labour than under ordinary circumstances is customary, depends very much on the habits of a people and even on idiosyncracies of the individual. Nothing could well illustrate this more forcibly than the diametrically opposite methods resorted to in the training of athletes in Europe and in India. Dr. Carpenter † mentions that the *lean* parts of beef and mutton constituted the principal food given by Jackson, a celebrated trainer of prize-fighters in modern times, and that stale bread was the only vegetable allowed; and Letheby ‡ mentions that King, the pugilist, whilst training, partook largely of lean beef and mutton, with toast or stale bread, but with very little potato or other vegetable; sugar was scrupulously avoided. On the other hand, the ordinary training food of professional wrestlers in this country, at least of Upper India, consists largely of sweetmeats, fat (ghee or clarified butter), and milk. Thus, the training-food of the European prize-fighter is of a highly nitrogenous character, whilst that of the Hindoo wrestler is decidedly carbonaceous. The inhabitants of mountainous districts in Central Europe also are said to place greatest

* *The Lancet*, 1876. Also *A Treatise on Food and Dietetics*—2nd Edition.
† *Human Physiology*—8th Edition, page 99.
‡ *Lectures on Food*—2nd Edition, page 121.

reliance on food of the latter character—bacon and sugar being favourite provisions when they have arduous journeys to perform.* That prolonged exertion is not incompatible with a food in which carbonaceous elements greatly predominate is further evident from the fact that nearly all beasts of burden are herbivorous; and bees, though constantly in motion, feed on saccharine material. Moreover, as the proportion of carbonaceous material contained in animal food is so very much smaller than what is contained in vegetables, and as only a certain, comparatively small, quantity of the nitrogenous element can be advantageously utilized by the system, it is wasteful to resort to very highly nitrogenised forms of food for the supply of the large amount of carbon which is required —and not only is it wasteful but injurious also, seeing that an unnecessary strain is thrown upon the excretory organs in getting rid of the surplus nitrogen before the carbon which is combined with it in the food can be made available for the production of force.

10. So far as I am aware, no systematic series of observations has been conducted on the precise food-requirements of the inhabitants of this country when undergoing laborious exertion as compared with the requirements when the body is at rest, so that (apart from what observation teaches as to the habits of the people generally) all inferences as to what these requirements are, are based on experiments made in Europe and on people accustomed to a far larger proportion of animal food than the great majority of the inhabitants of Eastern countries. In the light of what is now known as to the respective parts played by the nitrogenous and carbonaceous ingredients of food in the production of muscular action, it is doubtful whether the data which have been acquired by experiments on men accustomed to partake of a large proportion of albuminous principles in their food are strictly applicable to the poorer classes of this country. When such data are resorted to as a basis whereupon to frame dietaries suitable for native prisoners, it is found that the proportion of albuminates is considerably higher than the poorer classes are accustomed to, especially such of them as are habitually rice-eaters. A like discrepancy is found when the food of different classes in European countries is compared; and the effect of habit, as regards the amount and quality of food which is requisite for the maintenance of health, is strikingly shown in the case of soldiers when confined in civil prisons in England. It appears that they almost invariably lose weight, whilst civilians of their own age and former position in life do remarkably well on the prison dietary. The most obvious explanation of this discrepancy seems to be that the soldier since he joined the ranks has become accustomed to a diet consisting to a greater extent of animal food than he obtained before. It would, however, not be desirable, or indeed just to the public at large, that the acquired wants of the soldier should serve as the standard in providing for the ordinary food-requirements of the general prison population.

* Hermann's *Physiology*—Translated by Gamgee—2nd Edition, 1879.

CHAPTER II.

MOLESCHOTT'S "STANDARD DIET;" EDWARD SMITH'S ENGLISH IN-DOOR LABOURER'S DIETARIES; AND THE LABOURING DIET SCALES OF ENGLISH PRISONS.

11. The late Dr. Parkes, as is well known, studied the diet-question with the greatest care, and selected, as a "standard diet," a scale which had been prepared by Moleschott. This scale has been very generally accepted as suitable for Europeans undergoing a fair amount of mechanical labour, of an average height of five feet eight inches, and of an average weight of 150 lbs. It has, however, not been suggested, so far as I am aware, that this scale should serve as a standard for the construction of prison dietaries, but rather for the soldier and the public at large. The diet referred to is given in the following statement, the nutritive values being expressed in ounces of albuminates, fats, and carbo-hydrates; as also in grains of nitrogen and carbon:—

Moleschott's "Standard Diet."

Water-free substances given daily.	Ounces.	Nutritive value in grains.	
		Nitrogen.	Carbon.
Albuminates	4·58	316	1,068
Fats	2·96	...	1,024
Carbo-hydrates	14·25	...	2,768
TOTAL NUTRITIVE VALUE	...	**316**	**4,860**

This diet provides about 2 grains of nitrogen and a little over 30 grains of carbon per pound of the weight of the consumer, per diem—the proportion of the nitrogen to the carbon being as 1 to 15. The amount of fatty matter is nearly 3 ounces.

12. Some years ago Dr. Edward Smith conducted, on behalf of the Privy Council, a very extensive series of observations on the food of the labouring classes in England.* The following statement epitomises the result of these inquiries as regards the nature and amount of food upon which the poorer class of in-door labourers had to live and earn a livelihood. It will be observed that the nature of their work is not unlike what a large proportion of native prisoners have to perform in India:—

* *Sixth Report of the Medical Officer of the Privy Council*, 1864.

Dietaries of in-door labourers in England.

	Ounces weekly.			Daily nutritive value in grains.	
	Bread stuff.	Meat.	Fats.	Nitrogen.	Carbon.
Silk-weavers	152	7·25	4·50	164	3,945
Needle-women	124	15·0	4·50	135	3,271
Kid-glovers	140	18·25	7	173	4,089
Stocking-weavers	190·4	11·75	3·5	190	4,791
Shoemakers	180	15·75	5·75	188	4,528
Average daily nutritive value =				170	4,125
Omitting the needle-women, the average daily nutritive value =				**179**	**4,338**

The average daily amount of nitrogen entering into the composition of the food of these poor operatives is considerably less than two-thirds of the proportion given in Moleschott's standard diet, even after excluding the needlewomen from the computation; and the carbon also is less by over 500 grains. They appear, however, to consume a large quantity of fatty matter, the average daily amount, divided amongst the four classes, being a little over 5 ounces. The nitrogen to the carbon is as 1 to 24.

13. The dietaries of English labouring prisoners also have always been lower than Moleschott's standard. Doubtless, the framers of the jail diets took into consideration that a large proportion of the prisoners are from the lower classes and have been accustomed to live, as Dr. Edward Smith's tables show, very sparingly. Moreover, as the Jail Diet Committee which was recently appointed in England, and to which reference is made in the following paragraph, say, "the question of sufficiency cannot be dealt with entirely apart from the question of cost; and we conceive that we should ill-discharge our functions if we were to lose sight of the fact that prisoners are, to some extent, maintained at the expense of those whom they have injured." On the other hand, the diet scales of jails have, during recent years, usually been considerably more liberal than those of English poor-houses; and Dr. Letheby writes, "the dietaries of prisons are so greatly in excess of the union that in times of distress they offer encouragement for misdemeanour, in order that the prison may be reached in preference to the workhouse."*

14. The special committee above referred to was appointed, during 1877-78, to inquire into the dietaries of Local Prisons in England and Wales, "with a view to

*Op. cit., page 116.

introducing uniformity as far as possible," it being considered that a multiplicity of scales involved waste and confusion, and was bewildering to the staff. Their report is dated 27th February 1878, and was printed by order of the House of Commons in the following March. The dietaries proposed were accepted, and the Home Secretary issued instructions that they should be brought into operation from the 15th of May of the same year. Prisoners undergoing hard labour are divided into four classes:—class I being men of 7 days imprisonment and under; class II men of more than 7 days and not more than one month; class III more than one month and not more than four; and class IV more than four months. The dietaries for the first two of these classes of prisoners are considerably lower than those for classes III and IV, but they need not be especially noticed here.

15. The *average* daily allowance to men undergoing hard labour of between one and four months' imprisonment, and of those whose sentences exceed four months is, stated briefly, as follows:—

Daily average allowance of food to labouring prisoners in LOCAL *Prisons in England and Wales.*

CLASS OF PRISONERS.	OUNCES.										
	Bread.	Oatmeal.	Flour.	Cooked Meat.	Meat for soup.	Peas.	Potatoes.	Fresh Vegetables.	Onions.	Suet.	Salt.
III.—One to four months* ...	20·8	4	1·1	·85	1·3	1·3	8·0	·65	·18	·21	·5
IV.—Over four months* ...	23·4	6	1·7	1·1	1·7	1·7	9·2	·85	·2	·32	·5

* At the expiration of 9 months one pint of cocoa, with 2 oz. of extra bread, may be given at breakfast three times a week in lieu of one pint of gruel or porridge, if preferred.

The cooked meat is issued twice weekly, three ounces for dinner, on Mondays and Fridays, to the "one to four months'" class of prisoners; and four ounces on the same days to the "over four months'" class. Soup is issued on three days a week, the quantity of meat used in the preparation of the weekly allowance being 9 ounces to class III and 12 ounces to class IV. Prisoners of the former class, therefore, receive in the aggregate 15 ounces of animal food weekly, and those of class IV 20 ounces.

16. In the following statement these two dietaries have been resolved into the more important of their proximate alimentary constituents; and their dietetic values are also given in terms of nitrogen and carbon:—

The average daily nutritive values of the dietaries of labouring prisoners in the LOCAL *Prisons of England and Wales.*

WATER-FREE SUBSTANCES GIVEN DAILY.	CLASS III, ONE TO FOUR MONTHS.			CLASS IV, OVER FOUR MONTHS.		
	Ounces.	NUTRITIVE VALUE IN GRAINS.		Ounces.	NUTRITIVE VALUE IN GRAINS.	
		Nitrogen.	Carbon.		Nitrogen.	Carbon.
Albuminates	3·13	215	729	3·91	270	911
Carbo-hydrates	16·22	...	3,150	19·67	...	3·820
Fat	1·02	...	353	1·37	...	473
TOTAL GRAINS OF NITROGEN AND CARBON ...		215	4,232	...	270	5·204

These computations have been made from the weekly totals of the several ingredients which form the dietaries, and are, as regards the average daily amount of nitrogen, almost identical with the results obtained by the committee—the committee's nitrogen-figures being 216 and 270. The amount of carbo-hydrates in the dietaries, as estimated by the committee (16·65 and 20·17 oz.), is somewhat higher than is indicated in the above table, owing chiefly to the high carbon value accorded by the committee to bread. Dr. Parkes gives the percentage of carbo-hydrates in bread as 49·2, and this factor has been adopted in computing the value accorded to it in the present memorandum.* The nitrogen is to the carbon in round numbers as 1 to 20. The first diet contains a little over an ounce of fat, and the second a little over an ounce and a quarter.

17. As regards the suitability of these dietaries to the classes for which they were proposed, the following extract from the *Second Report of the Commissioners of Prisons* (July 1879), para. 58, may be cited:—"The deaths from natural causes during the year ended March 31st, 1879, were 167 in number, giving a ratio of 8·3 per 1,000 of the daily average population. This death-rate is lower than that of any year on record, and is as much as 2 per 1,000 lower than the average death-rate of the previous five years. It would perhaps be premature at present to connect this diminished mortality with any particular cause; but it is important to note the fact, because the health of the prisoners forms one very valuable test of the effect of some of the changes which have been introduced, especially of the uniform diet, and because an improvement in this regard has been the direct object of many of the steps which have been taken, and the Commissioners cannot therefore regard it as otherwise than

* In some recent analyses of bread by Dr. De Chaumont the carbo-hydrates were found to be equal to 45·9 per cent.—*Army Medical Reports*, Vol. XVIII, page 223.

gratifying that such an improvement should be coincident with the introduction of a uniform diet, and with the efforts they have made to promote the interests alike of the inmates of the prisons and the public at large." And the Commissioners in their *Third Report* (July 1880), the last which I have seen, write as follows (para. 73):—"The death-rate is again lower than in any previous year, and we cannot but regard this as a substantial proof that such changes introduced since the prisoners were transferred to us, or have any bearing on the health of the prisoners (the most important being the new diet), have been justified by their operation."

18. I have not been able to procure such full details regarding the dietaries in force in Convict Prisons in England, but in Appendix D to Volume I of the *Report of the Commissioners on the treatment of Treason-Felony Convicts* (dated September 1870), and in Appendix K to Volume III of the *Report of the Commissioners on the working of the Penal Servitude Acts* (dated July 1879), I gather that the following scales are allowed to convicts on *light* and on *hard*, and (at Milbank and Pentonville prisons) on *industrial* labour. The *light* labour consists of oakum-picking, etc., and *industrial* labour comprises weaving, shoe-making, etc.

Daily average allowance of food to convicts on light, on industrial and on hard labour in English CONVICT *Prisons.*

CLASS OF CONVICTS.	OUNCES.														
	Bread.	Oatmeal.	Flour.	Cooked Meat.	Meat for Soup.	Cheese.	Potatoes.	Fresh Vegetables.	Onions.	Suet.	Pearl Barley.	Cocoa.	Molasses.	Milk.	Salt.
Light labour	20·7	2	·6	1·7	1·7	·6	12·6	·6	·8	·1	·3	·5	1	2	·5
Industrial labour	21·1	2	1·2	2·3	1·1	·6	13·7	·3	·4	·2	·1	·5	1	4	?
Hard labour	24	2	1·2	2·1	2·3	·6	13·7	·6	·5	·2	·3	·5	1	2	·5

19. There is somewhat greater variety in the food issued to prisoners undergoing sentence of penal servitude and a more liberal allowance of animal food, the highest rate being a weekly allowance of 3 lbs. 5 oz. against 1 lb. 4 oz. given to class IV in local prisons. There is, however, no very material difference in the aggregate nutritive value of the dietaries of the two classes of prisons, as the oatmeal issued to convicts is less than half the amount given in local prisons, and no peas are given. The comparative value of the two dietaries will, however, be more readily perceived by a study of the following statement in which the average daily food-allowance is reduced to albuminates, carbo-hydrates and fats, as also to grains of nitrogen and carbon, than from a comparison of the several ingredients of which the dietaries are composed:—

The average daily nutritive values of the dietaries of light, industrial and hard labour convicts in English CONVICT *Prisons.*

WATER-FREE SUBSTANCES GIVEN DAILY.	LIGHT LABOUR.			INDUSTRIAL LABOUR.			HARD LABOUR.		
	Ounces.	NUTRITIVE VALUE IN GRAINS.		Ounces.	NUTRITIVE VALUE IN GRAINS.		Ounces.	NUTRITIVE VALUE IN GRAINS.	
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.
Albuminates	3·28	226	764	3·53	243	822	3·82	263	890
Carbo-hydrates	16·26	...	3,157	17·09	...	3,318	18·53	...	3,598
Fats	1·25	...	432	1·47	...	508	1·52	...	525
TOTAL GRAINS OF NITROGEN AND CARBON ...		226	4,353	...	243	4,648	...	263	5,013

It will be observed, as already remarked, that no very marked difference exists in the nutritive values of the labour dietaries in force in the two kinds of English prisons. Taking the diets of the "over four months" class in local jails and the hard labour class of convicts, we find that there is only a difference of seven grains in the nitrogen contained in their daily rations and of 191 out of a total of over 5,000 grains in the carbon.

20. This dietary appears to have been adopted on the recommendation of a special committee which sat in 1864, and has therefore been in force from sixteen to seventeen years, though there were some small modifications made in the original scale as regards giving it more variety by Lord Devon's commission in 1870.*

In 1878-79, again, a special commission (of which Lord Kimberley was president) was appointed to inquire into the working of the Penal Servitude Acts. The results given in their report (already referred to) as regards the dietaries are highly satisfactory. In paragraph 101 the commissioners state, "We are also satisfied that the

* This I gather from the following evidence given by Dr. Gover, the present Superintending Officer of Convict Prisons, before the Royal Commissioners in 1879:—

Question 1575.—Are the prisoners weighed? Yes.

Question 1576.—Do they increase in weight? The general tendency amongst the convicts is that they gain in weight.

Question 1577.—You gave evidence before Lord Devon's Commission? I did.

Question 1578.—I see that you were asked,—"Is it the rule in your experience that prisoners lose weight at Milbank?"

"*Answer.*—Yes; I find that they lose weight now somewhat more than they did, * * I think that about one-third of the prisoners lose in weight, speaking roughly, that is to say of the ordinary convicts"? Since that time the diet has been somewhat altered.

Question 1579.—In what respect has it been altered? It has been somewhat improved. There is more variety in the diet than there used to be.

Question 1580.—There was a change in the dietary, I observe, in 1864? Yes.

Question 1581.—Since that time there has been another change? Yes.

Question 1582.—Are you quite satisfied with the dietary? Quite satisfied.

Minutes of Evidence, Vol. II, page 123.

quantity of food contained in the several dietaries is fairly proportioned to the amount of labour required of the prisoners. We have arrived at this conclusion from personal observation, as the convicts seen by us at hard labour at Chatham, Portland, Dartmouth, and Portsmouth, appeared in excellent health and quite equal to the work upon which they were employed." And, in paragraph 102, they recommend that when, in exceptional cases, the diet is found insufficient "the medical officer should have the power of recommending an increased allowance of bread without, as at present, waiting for the previous sanction of a Director, and that all such cases should be brought before the Director at his next visit, whose duty it should be to make special inquiry into them." Finally the Commissioners in their remarks concerning the Scotch and the convict dietaries (paragraph 108) say—"We recommend such a revision of the former as may cause them to approximate closely to those in force in England, of the sufficiency of which we have received satisfactory evidence."

CHAPTER III.

THE ADAPTATION OF THE DIET SCALES OF LABOURING PRISONERS IN ENGLAND TO INDIAN REQUIREMENTS.

21. Testimony of the character cited as to the suitability of the maximum dietaries issued both to convicts and to labouring Local jail prisoners in England appear to be so conclusive as to warrant and even to invite the suggestion that they should, at all events for the present, serve as the basis for the construction of dietaries for labouring prisoners in other countries. Considering the previous habits of the inmates of English jails, the very small amount of animal food which has been found compatible with the exaction of hard labour, especially in the case of Local Prisons, is a noteworthy circumstance; and this, taken together with the high proportion of the carbonaceous to the nitrogenous ingredients in the food, seems to indicate in a special manner the suitability of such a standard to Indian requirements. Moreover, the lessons which a study of the history of these dietaries seem to teach have not that degree of uncertainty about them which must of necessity characterise lessons acquired by means of specially devised experiments in the carrying out of which more or less artificial conditions are inseparable. The experience gained in connection with the English prison diets has been very gradually acquired, and the unconscious subjects of the experiments belonged to the very class for whom it is desired to solve the extremely difficult problem of providing for their sustenance and at the same time carrying out the primary object of their imprisonment.

22. As to what is to be regarded as "sufficiency" in a prison diet, the Diet Committee of the English Local Prisons express themselves thus:—Sufficiency is not a quantity capable of demonstration. There is, at the outset, the defect inherent in

all scales, that a uniform diet is given to persons of various age, weight, height, idiosyncracy and physical conformation, but scales will, nevertheless, be always rendered necessary by the exigencies of administration wherever bodies of persons have to be dealt with in the mass. It is the duty of those who are called upon to frame scales of diet to be guided by averages, and it is the duty of those who use them to provide for exceptional cases by special means.

23. Bearing in mind the spirit of these observations, it may now be considered what proportion of the diet which has proved so successful in English prisons should be considered as sufficient for native labouring prisoners in India, and which of these two kinds of maximum labour dietaries should be selected. The latter point may be considered in the first instance. As already remarked, there is but very little difference in the aggregate nutritive value of the two dietaries. The little there is, is slightly in favour of the maximum Local Prison scale. The work and the length of the sentences of inmates of this class of prison correspond perhaps more closely with that of the majority of Indian prisoners than do the work and sentences of those undergoing penal servitude in England, so that, on the whole, the Local Prison dietary would seem to be the more suitable. Moreover, the classification of the prisoners who are placed on the two principal scales of the diets for labouring prisoners corresponds very closely with that commonly adopted in India—"One to four months'" and "over four months'" imprisonment. In India the more general classification is into "one to three months'" and "over three months'" imprisonment. It may be added that the labour diets of the Local Prison Committee form the bases for the principal non-labouring dietaries.*

24. The first question to be solved is what proportion of these English scales should be adopted for Indian prisoners. In attempting to frame such an estimate, it has been usual to accept the average relative weights of individuals as being the most satisfactory and practically attainable basis; though in estimating the food-requirements of the prisoners of a province the activity natural to the population, as well as the physique, must be prominently borne in mind. Acquaintance with the mere size of a furnace, for example, will not, of itself, suffice to enable a satisfactory estimate to be formed of the amount of fuel which it will consume. A small-built but a highly energetic people require, proportionately to their weight, considerably more food than an apathetic or indolent race, though, perhaps, it would be more correct to say that they require more of that kind of food which has been shown to be the ultimate source of energy. When, however, the ordinary habits of natives of this country are considered, it is clear that exceptional activity does not exercise a disturbing element in such a computation, for it is notorious that the disproportion in the amount of work which they perform is quite

* "We recommend," says the Committee, "that the articles of diet be the same to male prisoners with and those without hard labour; but that in the case of prisoners without hard labour, one-fifth of the total of articles served up in a solid form (or one-sixth of the whole) be deducted from the diet appropriate to the requirement arising when hard labour forms an integral part of the sentence."—*Report on Dietaries*, page 15.

as great as, if not greater than, the disproportion between the body-weight of a Hindoo and of an Englishman. There does not, therefore, seem to be any special objection in this instance to resorting to the basis for computing diets which is ordinarily adopted. The average weight of Englishmen may be said to range from 140 to 160 lbs. The weight of convicts, however, is probably below the mean of these figures, owing to the great majority of them coming from the poorly-nourished classes, and it would perhaps be nearer the truth to accept 145 lbs. as the average. The weight of the majority of prisoners in India ranges from 90 to 120 lbs., the mean weight would consequently be 105 lbs., and this is generally accepted. Possibly, however, to adopt 110 lbs. instead of the mean would diminish the margin of error, though this is considered to be a somewhat high average, especially for Bengalis.

25. Assuming that, under the conditions cited, the weight of the body furnishes a fairly correct guide to the food-requirements of the individual, the proportions of the proximate aliments supplied to the English Local jail-labouring prisoner which should be supplied to a native of India under like circumstances are calculated in the following table :—

The two principal dietaries of labouring prisoners in English Local Prisons adapted to the requirements of prisoners of an average weight of 110 *lbs.*

ONE TO FOUR MONTHS.					OVER FOUR MONTHS.				
OUNCES DAILY.			GRAINS DAILY.		OUNCES DAILY.			GRAINS DAILY.	
Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.
2·37	12·30	0·77	163	3,210	2·96	14·92	1·04	205	3,948

According to these scales native labouring prisoners of less than four months' imprisonment would receive daily about $2\frac{1}{3}$ oz. of dry albuminoid or nitrogenous substances, a little over $12\frac{1}{4}$ oz. of farinaceous and saccharine food (carbo-hydrates) with about $\frac{3}{4}$ oz. fat. The nitrogen contained in the diet is 163 grains and the carbon 3,210. Prisoners undergoing sentences of more than four months would receive nearly 3 oz. of albuminates, nearly 15 oz. of carbo-hydrates, and a little more than 1 oz. of fatty matter. These are equivalent to 205 grains of nitrogen and 3,948 grains of carbon. The proportion of the former to the latter is in both diets very nearly as 1 to 20. As already mentioned, the amount of nitrogenous food in the dietaries of labouring prisoners in local prisons is practically the same as is contained in the diets of convicts in penal jails, a maximum of 270 grains of nitrogen per diem in the former and of 263 grains in the latter. Seeing that this amount of nitrogen has been found sufficient for Europeans accustomed to partake more largely of nitrogenous food than the generality of natives of this country, it may be concluded that at least the nitrogen-requirements of native prisoners would be met by the adoption of such a standard as the foregoing.

CHAPTER IV.

THE NUTRITIVE VALUE OF THE DIET SCALES OF LABOURING PRISONERS AT PRESENT OR RECENTLY IN FORCE IN INDIAN JAILS.

26. The question as to how far the dietaries of labouring prisoners in India exceed or fall below this standard may now be considered. Tables will be found appended to this memorandum giving detailed statements of the composition of 151 hard-labour diets together with computations of their nutritive values. Nominally only 86 of these diets are in force at the present time; but in practice it is found that this number is considerably below the truth, even as regards labouring prisoners alone. This will become evident when the chief dietaries of the provinces come under review.

27. Every endeavour has been made to secure the correctness of the computations of the nutritive values of these numerous diets, still it must be clearly understood that at best such estimates can only convey an approximation of their values, although the probabilities of these being over or understated are about equally balanced. In a country like India, where the number of cereals and pulses resorted to as staple articles of food are so numerous, the construction of a really uniform dietary is hardly possible, certainly it is not possible to adopt one and the same kind of cereal and pulse for uniform and constant use.

28. Moreover, there are practical difficulties in deciding the equivalent values of these various food-stuffs, not only because the chemical analyses which have been made of many of them are not so complete as desirable, but there is also a want of definite knowledge as to their exact position as true aliments based on their adaptability for being assimilated. Unfortunately also there are some discrepancies in the results of the analyses of food grains and pulses which have been published. This makes it a matter of considerable difficulty to decide which of them should be taken as nearest to the truth. There is no doubt that the nutritive value of cereals and pulses presents considerable variations, not only from deterioration caused by attacks of insects, etc., but also according to the locality in which they are grown. Such discrepancies are common to the analyses of nearly all alimentary substances, and rice, which is said to constitute the chief food of one-third of the human race, may be cited as a notable example, especially as regards the important question of the proportion of nitrogenous matter contained in it.

29. The results, as the amount of albuminates in ten analyses of this cereal, which are now before me, vary from a minimum of 5 to a maximum of 11·7 per cent. In estimating the value of rice as an article of food it must be borne in mind that it is considered to be the most digestible of all cereals, so that, although most other food grains yield a higher proportion of nitrogen in the chemist's laboratory, many of them, are, nevertheless, far inferior as a source of nourishment owing to their indigestibility. Mayer, who analysed samples of rice at Madras, gives the proportion of dry albumi-

nates in it as 9·0 per cent., and Dr. Lyon found that a sample which he analysed in Bombay contained over 8 per cent. In his valuable memorandum on foods,* however, Dr. Lyon adopts a percentage of 7·3 for computing the proportion of albuminates in this cereal, and I have followed his example in the accompanying jail dietary tables, not only because this proportion appears to give a fair estimate of the quantity contained in an average sample of good rice, but also because it is very desirable that a uniform standard should be adopted in calculating the nutritive values in the various food grains in India.

30. For similar reasons I have followed Dr. Lyon in adopting a common factor for computing the amount of carbon in Indian cereals and pulses. As the factor made use of somewhat understates the average results of analyses as to the carbon value of the majority of these food-stuffs, there is less hesitation felt in adopting it. The extreme differences either way, however, are not very material. A uniform value has likewise been accorded to the different kinds of pulses in regard to nitrogen also, as, in most instances, there is no information available as to the particular pulse made use of, the term pulse (or dhal) being the only definition given for the guidance of jail officials. A table of the factors adopted will be found appended to this memorandum, so that any one interested in the subject may be able to extend the computations on the same bases.

31. Several attempts have been made to reduce the jail diets of this country into something approaching to uniformity, but, as may be inferred from what has been said above as to the number at present in force, without much success. In 1864 a Special Indian Jail Committee was assembled, and, among other matters, this question came under consideration. Their recommendations under this heading were chiefly to the effect that animal food should form a portion of the dietary of all labouring and under-trial prisoners—animal food being understood to include fish, flesh, and milk, with its various products; and that particular attention should be paid to the cooking, as also to securing that the prisoners should receive the prescribed quantities. "No scale of dietary," they remark, "can have fair play unless the proper dressing and the honest distribution of rations are rigidly attended to."

32. Appended to the Committee's report is a separate report by a Sub-Committee, which contains the scales of diet which had been adopted by the Government of Bengal on the recommendation of Dr. Mouat in 1860. In each of these scales intended for labouring and under-trial prisoners animal food is included, and they appear to have received the general approval of the Committee. A detailed statement of these particular diets will be found in Table I of the appendix to this memorandum, together with a computation of the number of grains of nitrogen and carbon in each. The annexed table epitomises this information, and, further, reduces the aggregate of each day's food into its principal alimentary constituents—albuminates, carbo-hydrates, and fats :—

* *Gazette of India*, May 19, 1877.

The chief proximate alimentary constituents of the dietaries for labouring and under-trial prisoners approved by the INDIAN JAIL COMMITTEE *of* 1864, *together with their nutritive values in grains of Nitrogen and Carbon.*

Nationalities.	Staple cereal of each diet.	(*a*) DIET WITH MEAT ON 4 DAYS A WEEK.					(*b*) DIET WITH FISH ON 4 DAYS A WEEK.				
		OUNCES.			GRAINS.		OUNCES.			GRAINS.	
		Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.
Bengalis, Ooryas, &c.	I. Rice ...	2·97	18·98	1·11	**205**	**4,763**	3·01	19·03	0·98	**208**	**4,736**
Natives of Behar, &c.	II. Rice and wheat-flour ...	3·63	19·11	1·24	**251**	**4,986**	3·66	19·17	1·11	**253**	**4,959**

33. These scales of diet appear to have been in force in Lower Bengal for about eighteen years. When compared with the scales of diet which have been adapted from the English Local Prison scales for men of an average weight of 110 lbs. (paragraph 25), it will be found that the amount of nitrogen in each day's food in the scale for Bengalis is precisely the same as is contained in the "adapted" maximum scale, 205 grains. The amount of carbon is greater by over 800 grains. The nitrogen is to the carbon as 1 to 23, and the daily diet contains a little over an ounce of fatty matter.

34. The diet scale for natives of Behar, and of Upper India generally, is a considerably more liberal one, owing to eight out of the twenty ounces of rice issued to Bengalis being replaced by ten ounces of wheat. If the maximum diet of English Local Prisons be accepted as a standard of sufficiency for men weighing 145 lbs., the Behari scale of diet above referred to should suffice for labouring prisoners of an average weight of 134 lbs.—a weight which comparatively few Beharis attain. The fish form of the dietary does not appear to call for special remark, but it may be mentioned that, as the proportion of albuminates is exceedingly variable in the different kinds of fish, it is not possible to express a definite opinion as to the precise value of this diet as compared with the meat form of it.

35. It is not clear to what extent this dietary has been taken as a basis for constructing scales for other provinces, but it is evident that in 1877, when another Indian Jail Committee, or Conference as it was designated, was assembled at Calcutta, it was found that such diversities existed as to the quantity and nature of the food given in the jails of different provinces that it was deemed expedient to suggest the desirability of introducing a new scale of dietary, at least for labouring prisoners. The following resolutions were adopted* :—

* *Report of Indian Jail Conference*, 1877, para. 26, page 142.

I.—That labouring prisoners sentenced for terms not exceeding three months should receive less than labouring prisoners sentenced for longer terms. Opinions were too conflicting to admit of our coming to any resolution as to the *amount* of reduction.

II.—That the following scale be laid down as a maximum for adult male prisoners sentenced to hard labour :—

(1) Grain 28 oz. (including 4 oz. pulse) in the form of sifted flour, or 26 oz. in the case of wheat, rice or barley.
(2) Green vegetables 6 oz.
(3) Fatty matter $\frac{1}{4}$ oz.
(4) Salt $\frac{1}{2}$ oz.
(5) Condiments $\frac{1}{4}$ oz., pepper from jail garden.
(6) Firewood 1 lb.

N.B.—Whenever it may be considered necessary, 4 oz. meat or fish, or an equivalent of milk, may be given instead of 4 oz. grain.

It is to be understood that reduction in one or more of the above articles does not warrant increase in any other.

III.—That meat is not a necessary article of diet, except in the case of Natives who are in the habit of eating it in free life (Dr. Henderson dissented from this resolution).

36. A comparison of the scales of diet recommended by this Conference with those approved by the Committee of 1864 shows that the principal difference consists in the adoption of the principle that the issue of animal food should be left to the discretion of the local jail authorities instead of making it a compulsory article of the labouring and under-trial dietary. In doing this it would seem that the Conference was influenced by the satisfactory experience which the jails of the North-West Provinces and Oudh, and also of the Central Provinces, furnished of the dieting of all prisoners without the issue of any animal food whatever. In the face of such experience it would have been manifestly unwise to recommend that the jail authorities of *any* province should be compelled to adopt an expensive article of food when experience had shown that it was unnecessary in some provinces. In connection with this matter the following remarks by the Committee on English Local Prison dietaries may be appropriately cited :—"There would be no difficulty in constructing a diet containing nutritive principles equal to those of meat out of oatmeal, peas, beans and fats, and this could be done at a third or fourth of the cost incurred by depending entirely upon the animal kingdom for these alimentary products." *

37. With regard to the apportioning of the quantities of grains and pulses, noted under clause (1) of the second resolution of the Conference, some confusion is manifest in the text, possibly owing to the transposition of the figures dealing with the quantities of the sifted flour and grain which are suggested for the various dietaries. The superiority of finely-sifted flour over the grain in its crude condition is so obvious as to be manifest on a moment's reflection. It is therefore probable that the text of the resolution of the Conference should be read thus :—"26 ounces (including 4 oz. pulse) of sifted *flour*, and 28 oz. of *grain* in the case of wheat, rice or barley." This is the interpretation which has been adopted in calculating the nutritive values of some of the principal forms into which the dietary which they recommended may be resolved. It is, however,

* *A Report on Dietaries in Prisons submitted to Parliament* in March 1878, page 31.

to be noted that in grouping wheat, rice and barley under one and the same heading, the Conference did not sufficiently consider the great importance, from a dietetic point of view, of the varying proportion of albuminates which these cereals contain. Rice, for example, with its average of 7 or 8 per cent. of nitrogenous substance, and wheat-flour, with a percentage of 13, cannot be taken as interchangeable measure for measure in any scheme of dietary.

38. Some of the principal forms into which the dietary suggested may be resolved are given in Table II of the Appendix, it being taken for granted that the phrase "sifted flour" (or *attah*) should be considered as implying not only wheaten flour, but also the flour of the other cereals which form staple articles of food all over India. The animal food form of the diet has been framed in this table on the scale approved by the Jail Committee of 1864, namely, at the rate of 1lb. per week of meat, fish, or milk in its various forms, being issued according to the requirements of different nationalities. The Conference does not mention the quantity of milk which they would recommend in lieu of meat or fish, consequently no computation of the nutritive value of this form of diet could be undertaken.

The following statement will serve as a summary of the details given in the larger table. The aggregate ingredients of the several diets are also reduced to their chief proximate alimentary principles:—

The chief Proximate Alimentary Constituents of the principal forms of the diet proposed for labouring prisoners by the INDIAN JAIL CONFERENCE *of* 1877.

STAPLE CEREAL OF EACH DIET.	(*a*) DIETS CONSISTING SOLELY OF VEGETABLE AND FATTY SUBSTANCES.					ANIMAL FOOD FORMS OF DIET—OPTIONAL.									
						(*b*) MEAT DIET.					(*c*) FISH DIET.				
	Ounces.			Grains.		Ounces.			Grains.		Ounces.			Grains.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
I.—Rice	2·85	21·66	0·51	197	5,047	3·03	19·89	·68	209	4,805	3·09	19·90	·56	213	4,778
II.—Wheat-flour ...	4·03	18·05	·76	278	4,707	4·07	16·51	·90	281	4,465	4·12	16·89	·57	284	4,438
III.—Barley-meal ...	2·94	19·45	·71	203	4,707	3·10	17·74	·86	214	4,465	3·13	17·78	·74	216	4,438
IV.—Jowar-flour ...	3·00	18·56	1·17	207	4,707	3·14	16·95	1·28	217	4,465	3·19	16·98	1·15	220	4,438
V.—Bajra-flour ...	3·33	17·87	1·33	230	4,707	3·43	16·35	1·42	237	4,465	3·48	16·38	1·29	240	4,438
VI.—Makki-flour ...	3·30	17·09	1·79	228	4,707	3·42	15·63	1·83	236	4,465	3·45	15·69	1·70	238	4,438
VII.—Raggi-flour ...	3·13	17·95	1·42	216	4,707	3·26	16·43	1·49	225	4,465	3·30	16·45	1·37	228	4,438
Daily average nutritive value.	**3·22**	**18·66**	**1·10**	**223**	**4,755**	**3·35**	**17·07**	**1·21**	**231**	**4,513**	**3·39**	**17·15**	**1·05**	**234**	**4,486**

39. The seven cereals which form the staple grain of each of these diet scales constitute the principal food grains of the three presidencies, though, for the most part, they are known under different names. The extent to which they are severally resorted to in jail dietaries varies considerably in the different provinces owing to the unequal extent in which they are cultivated. In the North-West Provinces four or five out of the eight are resorted to to a considerable extent, rice being adopted in only one jail; whereas in Lower Bengal rice and wheat alone are the cereals ordinarily made use of. These two cereals may be referred to, generally, as the grains which contain respectively the smallest and the highest proportion of nitrogenous material.

40. The diets in which these two grains form the staple cereals suggested by the Conference of 1877 approximate very closely in nutritive value (as inferred from their chemical composition) to the diets approved by the Committee of 1864, except as regards the fatty matter, which in the Conference diet has been materially reduced. In some of the other diets in which the staple cereal is richer in fatty matter than either rice or wheat, the curtailment of the amount of fat or oil separately issued is not manifest, but, on the contrary, the aggregate fat in the diet is greater than in the 1864 dietaries. In the non-animal food form of the rice diet there is a decrease of 8 grains of nitrogen per diem, but an increase of 284 grains in the carbon owing to 24 ounces of rice being issued instead of 20. In the animal food forms, however, of this diet there is a slight increase both in the nitrogen and carbon,—an increase of 4 grains of the former and of 42 of the latter over the 1864 diet. If the wheat-flour and non-animal food form of the Conference diet be compared in a similar manner, it is found that the Conference diet is richer in nitrogen by 27 grains but poorer in carbon by 279 grains. The meat form of the Conference diet contains 30 grains more nitrogen than the 1864 diet, but owing to 4 oz. of meat being given in lieu of 4 oz. of grain the carbon-value of the scale is less by over 500 grains. On the whole, therefore, there is practically but little difference between the recommendations of the Committee of 1864 and of the Conference of 1877 so far as the ultimate chemical constituents of the dietaries are concerned; but a pound of animal food per week constituted part of the regular food approved by the former, whereas the latter left the issue of this article to the discretion of the local authorities. The Conference, however, increased the rice ration by four ounces daily when meat was not given (or by two ounces should the interpretation of their intention adopted in this memorandum not prove to be correct), and the vegetables were increased by two ounces per diem.

41. The points of agreement and of contrast between the Conference scale and the dietary given in English Local Prisons will be clearly discerned in the following table, in which the chief proximate alimentary substances of the Conference diet and of the "adapted" Local Prison Scale (para. 25) are placed side by side, with *plus* and *minus* signs to the figures below to indicate the extent of the variation in the Conference diet from the adapted standard:—

The RICE *and the* WHEAT *forms of the Indian Jail Conference Dietary contrasted with the "one to four months" and "over four months"* ADAPTED *Scales of English Local Prisons.*

DIETARIES OF LABOURING PRISONERS.	OUNCES.			GRAINS.		OUNCES.			GRAINS.		OUNCES.			GRAINS.		OUNCES.			GRAINS.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
The *Adapted* English Scale "1 to 4 months" ...	2·37	12·30	0·77	163	3,210	2·37	12·30	0·77	163	3,210	2·37	12·30	0·77	163	3,210	2·37	12·30	0·77	163	3,210
	The Rice diet.					The Wheat diet.					The Rice-Meat diet.					The Wheat-Meat diet.				
Indian Conference Scales	2·85	21·66	0·51	197	5,047	4·03	18·05	0·76	278	4,707	3·03	19·89	0·68	209	4,805	4·07	16·51	0·90	281	4,465
Difference [Conference Scales] =	**+0·48**	**+9·36**	**−0·26**	**+ 34**	**+1,837**	**+1·66**	**+5·75**	**−0·01**	**+115**	**+ 1.497**	**+0·66**	**+7·59**	**−0·09**	**+ 46**	**+ 1,595**	**+1·70**	**+4·21**	**−0·13**	**+118**	**+ 1,255**
The *Adapted* English Scale "over 4 months" ...	2·96	14·92	1·04	205	3,948	2·96	14·92	1·04	205	3,948	2·96	14·92	1·04	205	3,948	2·96	14·92	1·04	205	3,948
	The Rice diet.					The Wheat diet.					The Rice-Meat diet.					The Wheat-Meat diet.				
Indian Conference Scales	2·85	21·66	0·51	197	5,047	4·03	18·05	0·76	278	4,707	3·03	19·89	0·68	209	4,805	4·07	16·51	0·90	281	4,465
Difference [Conference Scales] =	**−0·11**	**+6·64**	**− ·53**	**− 8**	**+ 1,099**	**+1·07**	**+3·13**	**−0·28**	**+ 73**	**+ 759**	**+ ·07**	**+4·87**	**−0·36**	**+ 4**	**+ 857**	**+1·11**	**+1·59**	**−0·14**	**+ 6**	**+ 516**

It will be seen that the above table is divided into two parts. In the upper part four of the scales of the Conference dietary are contrasted with the "one to four months" of the adapted English scale. Out of twenty headings under which comparisons are instituted, in four instances only are *minus* signs, and these refer to the fats. In the lower part of the table the same Conference scales are contrasted with the "over four months" adapted English scales, and here *minus* signs are appended to the Conference diet figures under six out of the twenty headings. Four of these are again due to paucity of fatty matter, and the remaining two refer to the same aliment in one diet, —a small difference in favour of the adapted English scale as against the non-animal food form of the rice dietary. The difference is very trifling, about one-tenth of an ounce of albuminates, which is equivalent to 8 grains of nitrogen. On the other hand, the *plus* signs appended to the Conference scales indicate in many instances a considerably more liberal supply of food, both in the nitrogenous elements and also in the carbo-hydrates. The latter are given in some of the scales to a considerably larger extent than would be accorded were the adapted English scale followed, so that if there be any truth in modern physiological teaching as regards the respective parts taken by the proximate aliments in the development of force, the extra amount of starchy food recommended by the Conference should not be objected to.

42. As, however, in most provinces a mixture of several cereals is adopted in prison dietaries, it may be that the mean value of the seven scales given in the table (para. 38) may furnish a closer approximate to the amount of nutriment which the Conference intended that their dietary should contain than is to be inferred from the data in the foregoing paragraph. Calculated in this manner, the daily value of the vegetable form of diet in terms of nitrogen and carbon is 223 grains of the former and 4,755 of the latter, the nitrogen being to the carbon as 1 to 21. Such a diet should be sufficient, on the English Local Prison standard, for labouring prisoners of an average weight of about 119 lbs.

43. As regards the curtailment of the fatty matter, the Conference appears to have suggested a retrograde step; for, although the deficiency is not so marked in all the scales, still it would probably be the opinion of most authorities that the amount is decidedly insufficient in some of them, and barely sufficient in others.

44. It does not appear that the recommendations of this Conference regarding dietary have as yet been very extensively adopted. So far as I can learn, the only jails in which the dietary proposed was introduced were those of Lower Bengal and of the Hyderabad Assigned Districts. There are, however, comparatively few prisoners in the jails of the latter province, the total labouring population barely reaching a daily average of 1,000.

45. In March 1879 the dietary which had been in force in Lower Bengal from about 1860 was changed, and the Bengali prisoners were placed on the diet proposed by the Conference. The diet of the natives of Behar and of Upper India generally,

confined in Bengal jails, was also modified. A detailed statement of the altered dietaries will be found given in Table III of the Appendix, a summary of which is furnished in the following statement:—

The Chief PROXIMATE ALIMENTARY CONSTITUENTS *of the* DIETARIES *adopted in* LOWER BENGAL *for Labouring Prisoners from March* 1879 *to March* 1880, *together with their Nutritive Values in grains of* NITROGEN *and* CARBON.

Staple Cereal of each Diet.	(*a*) DIETS CONSISTING SOLELY OF VEGETABLE AND FATTY SUBSTANCES.					DIETS CONTAINING ANIMAL FOOD—OPTIONAL.									
						(*b*) MEAT THREE TIMES WEEKLY.					(*c*) FISH THREE TIMES WEEKLY.				
	Ounces.			Grains.		Ounces.			Grains.		Ounces.			Grains.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
For BENGALIS:—															
I. Rice	2·78	20·56	0·50	192	4,814	2·91	19·21	0·63	201	4,628	2·94	19·25	0·53	203	4,607
For BEHARIS:—															
I. Rice and Wheat flour	3·39	19·62	0·62	234	4,814	3·52	18·27	0·75	243	4,628	3·55	18·29	0·66	245	4,607
II. Rice and Maize flour	3·26	20·51	1·24	225	5,171	3·39	19·16	1·37	234	4,985	3·42	19·18	1·28	236	4,964
III. Rice and Millet flour	3·16	21·00	1·03	218	5,171	3·30	19·64	1·16	228	4,985	3·33	19·66	1·07	230	4,964
Average value of diets for Beharis. } =	3·27	20·37	0·96	**226**	**5,052**	3·40	19·02	1·09	**235**	**4,866**	3·43	19·04	1·00	**237**	**4,845**

The animal food forms of the above scales were, however, not to be given as an ordinary prison dietary, except in those districts where the inhabitants are meat or fish-eaters, or when specially considered necessary. When meat or fish was given, 4 oz. was to be issued three times a week in lieu of an equal weight of grain. It is not clear to what extent advantage was taken of these clauses in the instructions issued to Superintendents of Jails, nor to what extent maize and millet were used in combination with rice in the Behari dietary. No mention is made of these two cereals in the diet scales proposed by Dr. Mouat—a mixture of wheat and rice being the only grains cited.

46. In order satisfactorily to understand the precise difference between the new dietary and the old, it will be advantageous to have the several ingredients of each dietary brought together, as well as a statement of the chief proximate principles into which each dietary may be resolved. This has been effected in the subjoined table; the rice and the rice-and-wheat dietaries for Bengalis and Beharis, which were in force from March 1879 to March 1880, being contrasted with those previously in force in Bengal. It will be observed that by the introduction of the new dietary the Bengali

labouring prisoners who were not accustomed to eat meat and fish when in their homes did not obtain these articles when in jail, as they would have done under the former regulations. This implied an average daily loss to this class of prisoners of $2\frac{1}{4}$ oz. of animal food. The fatty (or oily) matter was reduced all round by nearly half an ounce, but there was an increase of two ounces of rice and two ounces of vegetables per diem. This change expressed in terms of nitrogen and carbon implied a loss of 13 grains of the former (about the amount which would be contained in $1\frac{1}{4}$ oz. of uncooked meat), and a gain of 51 grains of carbon. If the amount of nitrogenous food allowed in Local prisons in England be accepted as sufficient, then the amount in the above scale of diet for Bengalis should suffice for persons of an average weight of 103 lbs. which, judging from the jail returns, appears to be somewhat above the mean weight of Bengali prisoners. Those of the Bengali prisoners who were accustomed to animal food when in their homes, were entitled to rations which are computed to be sufficient for men weighing from 107 to 108 lbs.

The diets in force in BENGAL *for labouring prisoners from March* 1879 *to March* 1880, *contrasted with the scales in force from* 1860 *to* 1879.

Periods during which the diets were in force.	Ingredients constituting the diets.								Proximate Aliments.			Nutritive value in grains of	
	Rice.	Wheat.	Pulse.	Animal food.	Vegetable.	Oil.	Salt.	Condiments.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	oz.	grs.	grs.
DIETS FOR BENGALIS—													
1860-79	20·5	...	4·1	2·3	4·10	0·68	0·51	0·50	2·97	18·98	1·11	205	4,763
1879-80*	22·5	...	4·1	...	6·15	0·25	0·51	0·25	2·78	20·56	0·50	192	4,814
Difference [1879-80]=	+2.0	...	...	−2·3	+2·05	−0·43	...	−0·25	−0·90	+1·58	+0·6	−13	+51
DIETS FOR BEHARIS, &C.													
1860-79	12·3	10·2	3·7	2·34	4·10	0·68	0·60	0·5	3·63	19·11	1·24	251	4,986
1879-80†	12·3	10·2	4·1	...	6·15	0·25	0·51	0·25	3·39	19·62	0·62	234	4,814
Difference [1879-80]=	...	...	+0·4	−2·34	+2·05	−0·43	−·09	−0·25	−0·24	+0·51	−0·62	−17	−172

* The rice form without animal food. † The wheat-and-rice form without animal food.

47. In the rice-and-wheat dietary which was adopted for Beharis there was (to such of these prisoners as, owing to previous habits when at large, were not entitled to meat or fish when in jail) an average daily loss of 2·3 oz. of animal food, and of nearly half an ounce of fatty matter. The only increments to the dietary were 2 oz. of fresh vegetables and a little less than half an ounce of pulse per diem. This diet is by no means an inferior one, for the amount of nitrogenous material which

is contained in it would, on the English Local Prison standard, suffice for labouring prisoners of an average weight of something over 125 lbs., and the proportion of carbonaceous food should suffice for men of about ten pounds heavier. Those of the Behari prisoners, whose habits when at large gave them a claim to be put on animal food when in jail, obtained rations which should suffice for men of an average weight of 130 lbs. There has been no curtailment as regards the amount of common salt issued—half an ounce per diem being the ordinary allowance in India, except in the North-Western Provinces where it is 100 grains, and in Madras [central jails] 1 oz.

48. During 1879 the health returns of the prisoners in Bengal, as in several other provinces, were exceptionally unfavourable; and as the period during which the new dietary was in force coincided with the period of maximum mortality, it was concluded that the high sickness and mortality in this particular province was attributable to insufficient food. In consequence of this inference extra rations were issued from March 1880 until July 1881, when completely new scales of diets were introduced with the sanction of the Local Government.

49. A detailed statement of the different forms of this dietary will be found in Table IV in the appendix, and their values in terms of nitrogen and carbon. A brief account of the dietary may, however, find a place here. The scales present much in common with those which were in force in this province between 1860 and 1879, but the animal food which constituted a part of the regular dietary of labouring prisoners (and was only issued to prisoners who were accustomed when at large to eat meat or fish when the "Conference diet" was in force) is now sanctioned for general issue at the discretion of the local jail officials. But when animal food is issued, 4 ounces of pulse (now increased to 6 ounces daily) is to be omitted. The amount of rice is increased by 2 ounces per diem, and the quantity of oil has been brought up to nearly the amount given in Dr. Mouat's scale. A new feature in the dietary is the issue of a morning meal consisting either of 3 ounces of soaked gram* or of 4 ounces of rice, bringing the daily quantity of rice up to 26 ounces when this grain is also adopted for the morning meal. The dietary is further enriched by the daily issue of an ounce of molasses and of half an ounce of tamarind.

The scales for Bengalis and Beharis are alike, with the exception that the staple

* Although the addition of this soaked gram (in some provinces parched gram is issued) materially increases the quantity of nitrogenous substances given to the prisoners, it is questionable whether more than a small proportion of the food contained in the gram is assimilated. Dr. Wm. Roberts, F.R.S., in his "Lumleian Lectures" (*Lancet*, 10th April 1880), says :—"In the raw state, starch is to a man an almost indigestible substance; but, when previously subjected to the operation of cooking, it is digested with great facility. Diastase has only a feeble action on the unbroken starch granule, even at the temperature of the body. In the lower animals, and in germinating seeds, the starch granule is probably attacked in the first instance by some other solvent, which penetrates its outer membranes, and thus enables the diastase to reach and act on the starchy matter contained within. By the aid of heat and moisture in the process of cooking the starch granule is much more effectively broken up. Its contents swell out enormously by imbibition of water, and the whole is converted, more or less completely, into a paste, or jelly, or mucilaginous gruel. It is in this gelatinous form exclusively, or almost exclusively, that starch is presented for digestion to man."

cereal in the dietary of the latter consists of a mixture of rice and wheaten flour, or of a mixture of rice and maize.

The nutritive values of the diet scales for labouring prisoners adopted in LOWER BENGAL *in July* 1881.

Nationalities.	Staple cereal of each diet.	(*a*) Diets consisting solely of vegetable and fatty substances.					Diets containing animal food—optional.									
							(*b*) Meat three times Weekly					(*c*) Fish three times weekly.				
		Ounces.			Grains.		Ounces.			Grains.		Ounces.			Grains.	
		Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
BENGALIS, Etc.	I. Rice with morning meal of gram	4·07	23·43	0·88	281	5,802	3·82	22·19	1·04	264	5,560	3·85	22·23	0·92	266	5,533
	II. Rice with morning meal of rice...	3·58	25·03	0·80	247	5,972	3·33	23·80	0·96	230	5,730	3·37	23·82	0·84	233	5,703
	Mean =	**3·82**	**24·23**	**0·84**	**264**	**5,887**	**3·57**	**22·99**	**1·00**	**247**	**5,645**	**3·61**	**23·02**	**0·88**	**249**	**5,618**
BEHARIS, Etc.	I. Rice (1) and Wheat-flour ...	4·66	22·50	1·00	322	5,802	4·42	21·26	1·16	305	5,560	4·46	21·29	1·04	308	5,533
	II. Ditto (2)... ...	4·18	24·10	0·92	289	5,972	3·94	22·85	1·08	272	5,730	3·97	22·89	0·96	274	5,703
	III. Rice (1) and Maize-flour ...	4·53	23·33	1·61	313	6,142	4·29	22·08	1·77	296	5,900	4·33	22·12	1·64	299	5,873
	IV. Ditto (2)	4·05	24·40	1·53	280	6,312	3·79	23·70	1·69	262	6,070	3·84	23·73	1·56	265	6,043
	Mean =	**4·35**	**23·58**	**1·26**	**301**	**6,057**	**4·11**	**22·47**	**1·42**	**284**	**5,815**	**4·15**	**22·51**	**1·30**	**286**	**5,788**

(1) The morning meal consisting of *gram*. (2) The morning meal consisting of *rice*.

50. The foregoing brief account will suffice to show that there is no lack of variety in this dietary, and the above table will serve to indicate the nutritive value of the several scales. Taken as a whole, the nutritive value of this dietary not only exceeds, under every heading, the "adapted" scale, which has been prepared from English Local Prison scales, but in most cases the amount of food actually issued is more than is given as a maximum dietary in either the Convict or the Local Prisons in England and Wales. The daily value of the diets for Bengalis ranges from 230 to 281 grains of nitrogen, and the carbon from 5,533 to nearly 6,000 grains. The value of the diet scales for Beharis and natives of Upper India generally ranges from 262 t 322 grains of nitrogen per diem, and the carbon from 5,533 to 6,312 grains. The fatty matters in the several diets range from a little under an ounce to a little over an ounce and three quarters, the diets in which maize forms a part being richer in fats than the others.

Computed on the English standard these scales should suffice for men weighing considerably more than the average weight of natives of Bengal and of Behar—the Bengali scales for a body weight of from 123 to 150 lbs.; and the Behari scales for persons weighing from 140 to 172 lbs. It was stated above that the Bengali and Behari diet-scales adopted by the Indian Jail Committee of 1864, and which were in force up to March 1879, should have sufficed for prisoners weighing respectively 110 and 134 lbs., so that the present scales are very materially more liberal than those formerly, and for so long a period, in force, and regarding which, judging from the evidence recorded by Mr. William Tallack (the secretary of the Howard Association) before Lord Kimberley's Jail Commission of 1878-79, there seems to have existed a feeling abroad that even the old scales were far from being deterrent. Mr. Tallack, on being asked to state generally his views on the subject of penal discipline both at home and abroad,* remarked amongst other things:—

"I may also observe that through, as I believe, inadequate regard to this necessity of rendering prisons deterrent and disagreeable, certain foreign countries are experiencing very inconvenient results, especially America, where there is little doubt that the prisoners have, in many cases, if not generally, been actually pampered, and as a result, or as one result, we find that American prisons are almost everywhere overflowing. I was talking yesterday to a friend of mine who has been a missionary of the Church of England in India for many years, and he told me that, with reference to the Bengal prisons, they are generally called by the natives 'our father-in-law's house,' by which they mean that they have a comfortable resource to fall back upon in case of need, and he further gave me an instance of the working of this feeling; he mentioned the case of one Bengal prisoner who, when his term of imprisonment was up, handed his brass water-jug to a comrade, saying 'take care of this for me until I return; I shall soon be back again to claim it.'"

51. Rice forms the staple cereal of the jail dietary in the adjoining province of Assam, as also in British Burma; and as the natives of these provinces present many features as to physique, habits, etc., in common with Bengalis, it will be convenient for purposes of comparison to consider the diet scales in force in these provinces in connection with those of Bengal. Full details regarding these two dietaries will be found in Tables V and XIII of the appendix.

52. In Assam, as in Bengal, two classes of prisoners are provided for,—Assamese and Bengalis forming one class, and Beharis and natives of Upper India generally the other. A summary of the nutritive value of these two dietaries is given below:—

Nutritive value of the diets in force for labouring prisoners in ASSAM.

NATIONALITIES.	Staple cereal of each diet.	OUNCES.			GRAINS.	
		Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.
Bengalis and Assamese ...	Rice	3·23	18·65	1·00	223	4,721
Beharis, Punjabis, etc. ...	Rice and Wheat	3·96	18·95	1·13	273	4,994

* *Minutes of Evidence*, Vol. II, 1879, Question 2656.

It will be perceived that they are virtually the same as those which were in force in Bengal from 1860 to 1879, except that fish (or an equivalent in milk) is given daily instead of four times a week. The Assamese and Bengali prisoners receive the equivalent of 223 grains of nitrogen, and the Beharis 273. An ounce of fat is contained in the daily ration of the former, and a little over an ounce in that of the latter. The scales furnish a more liberal dietary than is laid down in the "adapted" English Prison scale; indeed, the Assam scale for Beharis yields 3 grains of nitrogen more than is given as a maximum dietary to prisoners in local prisons in England, and 10 grains more than the maximum allowed to men undergoing penal servitude in English Convict Prisons; so that the remarks made by the Chief Commissioner of Assam in his review of the Jail Report for 1880, that "the scale of the province does not err on the side of severity," are more than supported by the evidence which the history of English Prison dietaries affords.

53. That the scale of diet which has been computed for men of an average weight of 110 lbs. on the basis of the English Local Prison scales (para. 25) is sufficient to maintain prisoners in a state of good health and is compatible with the exaction of hard labour, is, at least so far as the nitrogenous elements are concerned, amply supported by the facts furnished by the history of jails in Burma. Formerly the mortality in these jails was very high. In 1879 and again in 1880 the death-rate was lower than in any province under the Government of India. In the Local Jail Report for 1880, it is stated that, judged by the death-rate, the health of the convicts has been better than it has ever been before—23·4 per mille, which is the lowest on record:—

The nutritive value of the dietary for labouring prisoners in BRITISH BURMA *and of the* ADAPTED *English Local Prison scales.*

DIETARY.	UNDER 3 MONTHS.					OVER 3 MONTHS.				
	OUNCES.			GRAINS.		OUNCES.			GRAINS.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
Rice and meat ...	1·82	16·43	0·83	126	3,902	2·52	19·84	1·05	174	4,803
Rice and fish ...	1·87	16·44	0·72	129	3,879	2·59	19·90	0·83	179	4,757
Mean =	**1·84**	**16·43**	**0·77**	**127**	**3,890**	**2·55**	**19·87**	**0·94**	**176**	**4,780**
Adapted English Local Prison scales =	2·37	12·43	0·77	163	3,210	2·96	14·92	1·04	205	3,948

As already mentioned, a detailed statement of the dietary will be found in Table XIII. The above table gives the chief proximate alimentary principles into which the aggregate of the ingredients of each scale of diet may be resolved. The mean of the two dietaries has been computed, and the nutritive values of the adapted English Local Prison scales have been placed below for readiness of comparison. It will be observed that the Burma diet scales, on which the prisoners have been maintained in such excellent health, are, under all headings (except those giving the value of the carbonaceous food) lower, and in most instances considerably lower, than the "adapted" English scales. And yet out of 6,971 Burmese prisoners who were weighed during 1880, 5,206 were found to have gained in weight.

54. These results, moreover, speak strongly in support of the value of rice as an article of food. In estimating the food-requirements of natives of this country facts of the above character are of the greatest importance; they demonstrate beyond all question that the amount of nitrogenous food required, *when the rations are properly cooked and their issue carefully supervised*, is considerably less than is commonly supposed. In order to make sure that no mistake or misprint had occurred in the published dietary statement of the province, the Inspector General of Jails was asked if the diet was correctly given; and his reply was that, as regards the labouring diet scales, the published statement was perfectly correct. As regards the larger proportion of carbo-hydrates consumed, this experience will be accepted with satisfaction by those physiologists who, during recent years, have strenuously advocated the importance of a considerable preponderance of starchy and saccharine food as a means of nourishment for those who have to undertake mechanical labour. Though nominally sugar does not constitute an ingredient of the Burmese prison dietary, yet, as is well known, the transformation of starchy into saccharine matter is one of the first steps in the digestive process.

55. As an illustration of the caution which should be observed in attributing exceptional sickness and mortality amongst prisoners to insufficient food alone, the experience furnished by the Punjab jails may be appropriately cited. As will be found by a reference to Table IX in the appendix, the dietary in force for labouring prisoners in that province is far from illiberal; the lowest of the ordinary diet scales contains 301 grains of nitrogen and over 5,000 grains of carbon; and in two of the largest jails, where the mortality has been highest, special scales were sanctioned, the prisoners in the Rawal Pindi jail receiving a diet containing 342 grains of nitrogen and 5,070 grains of carbon, whilst the prisoners of the Rupar jail received food containing 500 grains of nitrogen and 6,771 grains of carbon.

56. When the data given in the above table are compared with those given under similar headings in the tables of dietaries of labouring prisoners in the Local and Convict jails of England, it will be found that the prisoners in the Punjab receive considerably more food than they do in England, and yet the mortality in the jails of that province during 1878 and 1879 was, almost unprecedentedly, high. In

Nutritive value of the several dietaries for labouring prisoners in the PUNJAB *jails.*

Alimentary principles.	ORDINARY DIETS.				MODIFICATIONS OF THE ORDINARY DIETS.						SPECIAL DIETS.	
	(*a*) Wheat, Barley and Mukka.	(*b*) Wheat, Barley and Bajra.	(*c*) Wheat, Jowar and Mukka.	(*d*) Wheat, Jowar and Bajra.	(*a*) Wheat, Barley and Gram.	(*b*) Wheat, Barley Gram and Mukka.	(*c*) Wheat, Barley and Gram.	(*d*) Wheat, Gram and Mukka.	(*e*) Wheat and Barley; Wheat and Gram.	(*f*) Wheat, Barley and Gram; Wheat and Gram.	(*a*) Rawal Pindi jail.	(*b*) Rupar jail.
Ounces of Albuminates ...	4·36	4·38	4·38	4·40	4·65	4·67	4·70	4·91	5·01	5·32	4·96	7·24
„ Carbo-hydrates	19·98	20·34	19·72	19·96	20·46	19·56	19·42	18·25	18·51	18·07	18·67	23·76
„ Fats	1·38	1·17	1·52	1·31	0·92	1·41	0·91	1·42	0·93	0·97	0·83	1·25
Grains of Nitrogen ...	301	302	302	303	321	322	324	339	346	367	342	500
„ Carbon ...	5,374	5,374	5,374	5,374	5,374	5,374	5,180	5,180	5,083	5,083	5,070	6,771

1879 the death-rate was 140 per mille. The diet scales at present in general use were introduced in June 1878. Those in force previous to this date sanctioned the issue of 24 ounces of meat per week. In the new diet the meat was replaced by a small extra allowance of pulse, and by a weekly issue of 28 ounces of parched gram. The proportion of nitrogen in gram is so high that its substitution for animal food, instead of reducing the albuminates of the diet, actually increased its value in a chemical sense; for whereas the former diet contained 264 grains of nitrogen and 4,975 of carbon, the present diet, taking the average of the ordinary scale in use, contains 302 grains of nitrogen and 5,374 grains of carbon.* The fatty matter in the diet averages about $1\frac{1}{4}$ ounce.

57. The mortality in the Punjab jails had commenced to be exceptionally severe before the new dietary was introduced; it reached its maximum of 140 per mille in 1879, and in 1880 it fell to 78·8—the fluctuations seeming to occur quite irrespective of the nature of the dietary. No appreciable result followed the issue of specially liberal scales of diet to the prisoners of the Rawal Pindi and Rupar jails. The death-rate in the latter was 216 per mille in 1878, 283 in 1879, and 104 in 1880, the decline in the mortality being contemporaneous with its decline in most other jails.

As if to give the recent dietary-experience amongst prisoners in this province almost the character of a specially devised experiment, the new scale had scarcely been adopted in the large jail at Umballa when the old scale was reverted to and retained until the middle of 1880. Nevertheless this jail became one of the most unhealthy in the province. In 1878 the death-rate was 235 per 1,000 of its average daily strength, and in 1879 it reached 332. In 1880, however, the mortality fell to 81·3 per mille, as it has already been stated to have done in most other jails in the province.

* *Vide* Foot-note to para. 49.

58. The diet scales in force in the North-Western Provinces and Oudh jails are given in detail in Table VI of the appendix, and a summary of their nutritive values is given in the subjoined statement :—

The nutritive values of the several diet scales for labouring prisoners in force in the NORTH-WESTERN PROVINCES *and* OUDH *jails; and the average daily value contrasted with the English Local Prison scales.*

Staple Cereals of each Diet.	3 MONTHS AND UNDER.					OVER 3 MONTHS.				
	OUNCES.			GRAINS.		OUNCES.			GRAINS.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
I.—Wheat	3·37	16·90	·56	233	4,261	4·69	19·66	·63	324	5,128
II.—Bajra	2·65	16·71	1·15	183	4,261	3·97	19·45	1·23	274	5,128
III.—Maize	2·62	15·89	1·63	181	4,261	3·94	18·63	1·71	272	5,128
IV.—Jowar	2·26	17·46	·99	159	4,261	3·62	20·15	1·07	250	5,128
V.—Wheat and Barley	2·81	17·62	·53	194	4,261	4·13	20·36	·61	285	5,128
VI.—Bajra and Maize	2·63	16·31	1·39	182	4,261	3·95	19·04	1·47	273	5,128
VII.—Jowar and Bajra...	2·47	17·07	1·07	171	4,261	3·79	19·81	1·15	262	5,128
VIII.—Jowar and Maize	2·46	16·66	1·31	170	4,261	3·78	19·39	1·39	261	5,128
Average nutritive value ... ... =	**2·66**	**16·83**	**1·08**	**184**	**4,261**	**3·98**	**19·56**	**1·16**	**275**	**5,128**
English Local Prison Scale =	3·13	16·22	1·02	215	4,232	3·91	19·67	1·37	270	5,204
Adapted ditto ... =	2·37	12·30	0·77	163	3,210	2·96	14·92	1·04	205	3,948

As will be seen from the above table, four cereals constitute the principal ingredient in these diets, wheat being considerably the best, and jowar the worst, in point of nutritive value. Animal food (except the fatty matter specially issued) forms no part of the diet scales of these provinces, so that we are here furnished with the experience of feeding an average daily population of some 30,000 prisoners on a strictly vegetable diet. The inhabitants of these provinces are on the average taller and heavier men than those of Lower Bengal, Assam, and Burma; but the average weight of prisoners of even the North-Western Provinces and of Oudh is below the standard of 110 lbs., which was adopted in a previous paragraph (para. 25) in computing the proportion of the English Local Prison dietary which should suffice for native prisoners in this country. It will be observed that the adapted English scales, which for facility of comparison have been inserted in the table, are, under every heading, con-

siderably smaller than the average nutritive value of the North-Western Provinces' dietaries; the latter may, indeed, be said to be practically identical with the actual English scales. So that if weight have any influence on the food-requirements of the body, it may be assumed that the labouring prisoners in these provinces are, weight for weight, considerably better fed than labouring prisoners in England.

59. In a former paragraph it was mentioned that, although the several recognised labouring diet scales in India did not exceed 86 or so, nevertheless that the scales actually adopted in practice greatly exceeded this number, the nutritive values of 151 being computed in the tables attached to this memorandum. This number would doubtless require to be materially augmented were information generally available as to the kind and quantity of food grains actually issued to the prisoners in the several jails. A statement of this kind has been kindly furnished by Dr. Walker, the Inspector General of Jails for the North-Western Provinces and Oudh, and from this statement Tables VII and VIII in the appendix have been prepared. Six of the larger district and six of central jails were taken at random. The aggregate of the amount of the several cereals issued in each jail during 1880 was divided by 366 so as to obtain a daily average based on a whole year's expenditure. The amount of the nitrogen and carbon in the several ingredients was then computed, as also the fatty matter in the aggregate of each diet. An epitome of the result will be found in the subjoined statement:—

A Summary of Tables VII and VIII giving the daily nutritive values of the diets which were actually issued to labouring prisoners during 1880, *in six District and in six Central Jails of the North-Western Provinces and Oudh.*

DISTRICT JAILS.							CENTRAL JAILS.						
Jails.	One to three Months.			Over three Months.			Jails.	One to three Months.			Over three Months.		
	Nitrogen.	Carbon.	Fats.	Nitrogen.	Carbon.	Fats.		Nitrogen.	Carbon.	Fats.	Nitrogen.	Carbon.	Fats.
	grs.	grs.	oz.	grs.	grs.	oz.		grs.	grs.	oz.	grs.	grs.	oz.
Allahabad ...	242	4,278	·59	333	5,145	·67	Allahabad ...	313	4,272	·76	404	5,139	·84
Bareilly ...	214	4,261	·66	305	5,128	·74	Bareilly ...	226	4,261	·70	318	5,128	·78
Benares ...	182	4,431	·63	273	5,298	·70	Benares ...	187	4,414	·69	278	5,281	·77
Meerut ...	280	4,261	·65	371	5,128	·73	Meerut ...	273	4,261	·63	364	5,128	·71
Moradabad ...	193	4,261	·53	284	5,128	·61	Agra	220	4,346	·74	311	5,213	·82
Rai Bareilly ...	188	4,261	·65	279	5,128	·73	Lucknow ...	276	4,788	·81	367	5,655	·89
Average =	**216**	**4,292**	**·62**	**307**	**5,159**	**·69**	*Average* =	**249**	**4,390**	**·72**	**340**	**5,257**	**·80**

60. The weight of the several cereals issued was in most instances strictly in accordance with the regulations in force, but, as will be seen from the above epitome of Tables VII and VIII, the nutritive value of the aggregate of the diets in the several jails ranges, as regards the albuminates for instance, in the "one to three months" scales of the district jails, from 182 grains of nitrogen at Benares to 280 at Meerut; and in the "over three months" scales, from 273 grains to 371 respectively in the same prisons. In the central jails the nitrogen contents of the average diet ranged in the "one to three months" class, from 187 grains at Benares to 313 at Allahabad; and in the "over three months," from 278 at Benares to 404 at Allahabad. The dietary of both the Benares jails is therefore lower than that of the other jails. This is chiefly owing to the smaller proportion of wheat and gram as compared with other grains, which was issued to the prisoners at Benares during 1880. Judged by the mortuary returns, however, the scales appear to have been sufficient; for, whereas the death-rate amongst the prisoners in those district and central jails which received the most liberal diets was, at Meerut, 29·2 and 34·0 per mille, at Allahabad 26·3 and 43·4 respectively; the death-rate in the district and central jails of Benares was only 18·0 and 9·7 per 1,000. It only remains to be noted that particular attention is paid in these provinces to providing the prisoners with fresh vegetables and with such sub-acid fruits as may be procurable, with a view to counteracting any tendencies to scurvy.

61. The dietary of prisoners in the jails of the Central Provinces was modified in 1877 chiefly by the reduction of the amount of grain issued to the extent of about 4 ounces. Table X gives the former as well as the present or reduced scale; and the sub-joined statement gives the nutritive values of the aggregate ingredients of both:—

Nutritive value of the former or standard scale, and of the present or reduced scale, of dietary for labouring prisoners in the CENTRAL PROVINCES.

DIETARIES.	6 MONTHS AND UNDER.					OVER 6 MONTHS.				
	OUNCES.			GRAINS.		OUNCES.			GRAINS.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
Former or standard scale	4·40	20·61	1·32	304	5,484	4·56	20·91	1·51	315	5,646
Present or reduced scale	3·98	17·79	1·17	275	4,787	4·13	18·10	1·36	285	4,949
Extent of reduction	0·42	2·82	0·15	29	697	0·43	2·81	0·15	30	697

The adoption of the reduced scale of diet was, however, not general until the end of 1878, and even then two large jails—Nagpur and Jubbulpore—were not able to give the reduced dietary a trial owing to prevailing sickness. In November 1880, the reduced scale was introduced into the Nagpur jail, but it has not as yet been considered expedient to make any change in the dietary at Jubbulpore.

62. The reduced scale of the "six months and under" class of prisoners contains 29 grains less of nitrogen and 697 grains less of carbon; and the scale of the "over six months" class, 30 grains of nitrogen and nearly 700 of carbon less than the old standard scale. But even this reduced scale is, under almost every heading, more liberal than the maximum diet supplied to prisoners in either Convict or Local prisons in England. The "under six months" reduced scale of the Central Provinces contains 60 grains of nitrogen more than is supplied to labouring prisoners of less than four months' imprisonment in English Local prisons, and 5 grains more than is contained in the maximum scale allowed in England. The carbon in the reduced scale of the "under six months" class in the Central Provinces exceeds the amount in the English scale by 555 grains, but the scale for the "over six months" class contains 255 grains less than the maximum English scale. This is the only heading under which the Central Provinces' "reduced" scale does not, and generally to a considerable extent, exceed the English dietary in nutritive value. Weight for weight, therefore, a Central Provinces' prisoner even on the "reduced" scale receives much more food than any hard-labouring prisoner in England.

63. As has already been stated a scale of dietary based on the recommendations of the Indian Jail Conference was adopted in the jails of the Hyderabad Assigned Districts. The staple cereal in this new diet consisted of a mixture of wheat and jowar, as was also the case in the diet which it replaced. In the new scale, however, the proportions in which the cereals were issued were, to a certain extent, reversed, the weekly amount of wheat being reduced from 79 ounces to 66, and the jowar increased from 66 to 96 ounces. The fatty matter issued was also reduced. The other changes, which are of a minor character, can be ascertained by referring to Table XI in the appendix, where full details are given. This table is epitomised in the statement given below, which also gives the proximate aliments into which the food-stuffs of the diets may be resolved:—

The nutritive values of the former and of the present scales of diet for labouring prisoners in the HYDERABAD ASSIGNED DISTRICTS.

DIETS IN FORCE TILL TOWARDS THE END OF 1879.										DIETS IN FORCE FROM END OF 1879 TILL MARCH 1881.										PRESENT MAXIMUM DIET.				
UNDER 3 MONTHS.					OVER 3 MONTHS.					UNDER 3 MONTHS.					OVER 3 MONTHS.					Ounces.			Grains.	
Ounces.			Grains.		Ounces.			Grains.		Ounces.			Grains.		Ounces.			Grains.						
Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
5·11	20·51	1·19	353	5,585	5·16	21·22	1·20	356	5,738	3·08	16·08	0·91	213	4,155	3·53	19·15	1·04	244	4,902	4·05	20 22	1·32	280	5,328

64. It is quite clear that the scales of diet in force previous to the introduction of what was termed the Conference scale were exceedingly high; even the "under three months" convicts received a considerably more liberal supply of food than is contained in the maximum scale sanctioned for either penal or other convicts in England. The Conference scale which was devised was by no means deficient in nutriment; taking the average of the wheat and jowar-diet days, when compared with the scales of the English Local Prisons, it will be found that the difference is not great.

DIETS.	Under 3 Months.					Over 3 Months.				
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
English Local Prison	3·13	16·22	1·02	215	4,232	3·91	19·67	1·37	270	5,204
Berar Conference scale	3·08	16·08	0·91	213	4,155	3·53	19·15	1·04	244	4,902
Difference =	0·05	0·14	0·11	2	77	0·38	0·52	0·33	26	302

When the difference in the weight of the two races is considered, and, possibly also, the amount of hard labour undergone (for, as a whole, the above scale is higher than the dietary of penal convicts even), there can be little hesitation in saying which of the two classes of prisoners were most liberally dieted.

65. This Conference scale was introduced into the several jails at various dates towards the end of 1879, but was set aside owing, apparently, to an outbreak of "scurvy" during the later months of 1880 in two out of the six jails—at Amraoti and Akola. The diet had been adopted at the Amraoti Jail in August 1879, and the first admission into hospital from "scurvy" took place in August 1880, an interval of just one year. At Akola the diet was introduced on the 1st October 1879; 1 case of scurvy was admitted in June (just 9 months after the new diet had been in force); 2 in August, 10 in September, 11 in October, 15 in November, and 4 in December. During 1878, when the former exceptionally liberal diet was in force, 106 admissions from scurvy were returned from this same jail. It does not therefore seem probable that the scurvy outbreak of 1880 can with any show of reason be attributed to deficient food. It may be mentioned that the disease frequently returned as "scurvy" in this country is by no means uncommonly met with in well-to-do and well-fed people during exceptionally severe malarious seasons. Like most other diseases, its character is aggravated from insufficient or improper food, but very severe forms of it have often been noticed when no question as to insufficient food could be entertained.

66. In March 1881 another scale of diet was introduced, the ingredients in which and their approximate nutritive value will be found given in the table above referred to (para. 63). This diet scale contains 10 grains of nitrogen and 124 of carbon more than the maximum diet given to labouring prisoners in England.

67. As will be seen from Table XV in the appendix, the jail in the city of Bombay has a dietary differing somewhat from the dietaries in force in the other jails of the Presidency. The staple cereals of the former diet consist of a mixture of wheat and rice, whereas in the mofussil jails the staple cereal consists either of wheat, bajra, or jowar. The subjoined statement gives a summary of the nutritive values of the several scales, from which it will be seen that the labouring prisoners in the Bombay City Jail receive a dietary containing 209 grains of nitrogen and 4,011 of carbon. It is a purely vegetable diet, but animal food may be given if ordered by the Medical Officer.

Nutritive value of diets for labouring prisoners of the BOMBAY *City Jail, and of other jails in the Presidency.*

JAILS.	Staple cereal of each diet.	ON INTRA-MURAL OR MEDIUM LABOUR.									
		WITH MEAT.					WITHOUT MEAT.				
		Ounces.			Grains.		Ounces.			Grains.	
		Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
Bombay City Jail* ...	Wheat... ...	...	...	...	...	...	3·03	15·57	0·81	209	4,011
Other jails in the Presidency	Wheat... ...	3·33	14·54	·99	230	3,943	3·77	17·69	0·72	260	4,367
	Bajra	2·69	14·36	1·52	186	3,943	3·13	16·53	1·24	216	4,367
	Jowar	2·39	14·99	1·37	165	3,943	2·83	17·13	1·10	195	4,367
AVERAGE NUTRITIVE VALUE =		**2·88**	**14·63**	**1·29**	**194**	**3,943**	**3·24**	**17·12**	**1·02**	**224**	**4,367**
		ON *Bonâ-fide* HARD LABOUR.									
Bombay City Jail* ...	Wheat... ...	...	...	...	...	...	3·03	15·57	0·81	209	4,011
Other jails in the Presidency	Wheat... ...	4·03	17·58	1·91	278	5,014	4·58	20·28	1·56	316	5,544
	Bajra	3·26	17·38	2·54	225	5,014	3·81	20·07	2·19	263	5,544
	Jowar	2·90	18·12	2·37	200	5,014	3·45	20·81	2·02	238	5,544
AVERAGE NUTRITIVE VALUE =		**3·39**	**17·69**	**2·27**	**234**	**5,014**	**3·95**	**20·39**	**1·92**	**272**	**5,544**

* No distinction made between medium and hard labour.

In the other jails of the Presidency a distinction is made between medium and hard labour, and the diet scales adapted accordingly; moreover, animal food appears to be issued in lieu of pulse at the discretion of the local officials. The substitution of animal food for pulse, however, reduces the value of the diet considerably, when the value is judged by the proportion of nitrogenous and carbonaceous substances which it contains. The wheat-diet scale, for example, with pulse contains 260 grains of

nitrogen and 4,367 grains of carbon; whereas the same scale with meat in lieu of pulse, contains only 230 grains of nitrogen and 3,943 of carbon—a decrease of 30 grains of nitrogen and of 424 of carbon. It will be noted that considerable difference exists in the nutritive value of the several diets according as wheat or jowar or bajra forms the staple ingredient; but as it is probable that these cereals are, to a greater or less extent, issued alternately in most jails, the mean of the dietaries may, possibly, serve to convey a more accurate estimate of the nutritive value of the food actually issued.

68. As the Bombay prison dietaries are not issued according to length of imprisonment (*i.e.*, to prisoners of under or over three or four months), it is not practicable to institute close comparisons between the scales in force here and those in force in England; but, comparing the maximum scale of the English Local Prisons with the maximum of the average of the Bombay Mofussil jail scales, the results are as follows:—

Maximum Prison Dietaries.	Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.
	oz.	oz.	oz.	grs.	grs.
Bombay Presidency... ...	3·95	20·39	1·92	272	5,544
Local Prisons, England ...	3·91	19·67	1·37	270	5,204
Difference =	0·04	0·72	0·55	2	340

It will be seen that the difference is in favour of the Bombay diet under every heading, so that, man for man, and not merely weight for weight, the hard-labouring native prisoners in Bombay receive more food than hard-labouring prisoners in England. The ordinary medium-labour scale in Bombay is higher than the "adapted" maximum English Local Prison scale (para. 25).

69. In the Madras Presidency the numerous diet scales which were formerly in force for labouring prisoners have been reduced to two classes,—the dietaries for central jails, and those for the district and subsidiary jails. In both classes the staple cereals are ragi, bajra (cumboo), and jowar (cholum); any or all to be adopted at the discretion of the local officials; but 24 ounces of ragi or jowar is to be considered as equivalent to 25 ounces of bajra. In the central jails 1½ lb. of rice is issued weekly. Fifteen ounces of animal food is also issued weekly in these jails, as also to convicts of "over four months" in the district jails. The other ingredients entering into the diets will be found tabulated in Table XVI, and their values computed in terms of nitrogen and carbon.

It is probable that two, if not all three, cereals are resorted to in most jails; hence, in estimating the value of the dietary of the labouring prisoners of the

Presidency, it will be advisable to take the mean of the three scales for each of the two classes of diets. The subjoined statement gives the nutritive value of each scale for the central and for the district jails separately; as also the daily average value as aliments of the combined scales of each class of prisons.

Nutritive value of the diets in force for labouring prisoners in the MADRAS *Presidency.*

STAPLE CEREAL OF EACH DIET.	CENTRAL JAILS.					DISTRICT AND SUBSIDIARY JAILS.									
						CONVICTS OF FROM ONE TO FOUR MONTHS.					CONVICTS OF MORE THAN FOUR MONTHS.				
	OUNCES.			GRAINS.		OUNCES.			GRAINS.		OUNCES.			GRAINS.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
Ragi	3·36	18·67	1·89	232	5,064	2·91	15·93	1·62	201	4,333	3·34	18·09	1·99	231	4,980
Cholum	3·23	19·24	1·66	223	5,064	2·78	16·49	1·40	192	4,333	3·18	18·75	1·73	220	4,980
Cumboo	3·62	19·20	1·84	250	5,210	3·17	16·44	1·58	219	4,478	3·65	18·68	1·94	252	5,150
Average nutritive value =	**3·40**	**19·04**	**1·80**	**235**	**5,113**	**2·95**	**16·29**	**1·53**	**204**	**4,381**	**3·39**	**18·52**	**1·89**	**234**	**5,037**

It will be observed that these diets are richer in fatty substances than jail dietaries ordinarily are, each scale containing from 1½ to 2 ounces. The central jail labouring diet contains an average of 235 grains of nitrogen and 5,113 of carbon. The "over four months" diet of the district jails is almost of the same value; and the "under four months" scale contains an average of 204 grains of nitrogen and 4,381 of carbon.

Taken altogether, these dietaries are considerably higher than the standard of the *adapted* English Local Prison scale, but the average value of the maximum Madras scale contains 35 grains less nitrogen and 91 less carbon than the maximum actual Local Prison diet. It will be recollected that the maximum Bombay scale exceeded the maximum of English Local Prisons.

70. The dietaries in force in the jails of Mysore and Coorg do not call for special remark. The ingredients entering into the labouring diet scales will be found cited in Table XII of the appendix, together with nutritive values in terms of nitrogen and carbon; and a summary of this statement is given below. From this it will be seen, that the nitrogen contained in the three scales ranges from 211 to 245 grains, and is to the carbon about as 1 to 21 or 22. The fatty matter ranges from about 1¼ to 1½ oz.

The nutritive value of the diets for labouring prisoners in the Jails of MYSORE *and* COORG.

Staple Cereal of each Diet.	6 months and under.					Over 6 months and up to 2 years.					Over 2 years.				
	Ounces.			Grains.		Ounces.			Grains.		Ounces.			Grains.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
Rice and Ragi	3·06	18·91	1·27	**211**	**4,824**	3·36	19·48	5·51	**232**	**5,088**	3·55	20·56	1·61	**245**	**5,376**

71. Table XIV in the appendix details the ingredients, and gives the nutritive value of the dietaries in force for *Third-class* and *Chain-gang* convicts at the penal settlement in the Andaman Islands. The ordinary dietary consists of two scales: in one rice forms the staple cereal, and wheat in the other. Fish forms a part of each diet to the extent of $1\frac{1}{4}$ lb. per week. When fish is not procurable, which was the case on 100 days during 1880, an extra allowance of rice is issued in lieu of it. There are consequently four scales of diet in force.

The subjoined statement gives the nutritive value of each of these scales.

The nutritive value of the dietaries for Third-class and Chain-gang convicts at the ANDAMAN ISLANDS *Penal Settlement.*

Staple Cereal of each Diet.	Ordinary diets.					Diets when fish is not procurable.				
	Ounces.			Grains.		Ounces.			Grains.	
	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.	Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.
Rice	3·63	23·62	1·39	251	5,915	3·52	27·43	1·35	243	6,615
Wheat	4·55	18·64	1·60	314	5,235	4·43	22·46	1·56	306	5,935
Average nutritive value ... ... =	**4·09**	**21·13**	**1·49**	**282**	**5,575**	**3·97**	**24·94**	**1·45**	**274**	**6,275**
Maximum diet of convicts in English Convict Prisons	3·82	18·53	1·52	263	5,013	3·82	18·53	1·52	263	5,013

The convicts are permitted to select either the rice or the wheat form as the rations are passed round. The average daily nutritive value of the two scales of the ordinary dietary is equivalent to 282 grains of nitrogen and 5,575 grains of carbon, so that it is better than the maximum diet issued to convicts in England by 19 grains of the former and 562 of the latter; or, when fish is not available, the increase equals 11 grains of nitrogen and 1,262 grains of carbon.

CHAPTER V.

SUMMARY AND CONCLUSIONS.

72. As it has been necessary to enter into so many details in connection with these prison dietaries, it may be desirable that a summary should be prepared of the salient points of the memorandum. Discussion of abstruse physiological questions has been, so far as possible, avoided, but the question as to what constitutes the essential alimentary principles of a dietary suitable for native labouring prisoners could not be satisfactorily examined without a brief reference to some of the more recent researches which have been made on the subject, and which have, more or less completely, reversed the views on important points previously entertained by most writers on dietetics. It has been pointed out that, owing principally to the teachings of Liebig, very great prominence has been given to the necessity of increasing the albuminoid or nitrogenous principle of food in proportion to the amount of work exacted, on the supposition that the nitrogenous, chiefly muscular, tissues of the body are rapidly wasted as a result of exertion, and that the non-nitrogenous elements of food (starch, sugar, fat, etc.) were simply useful in the production of heat.

73. This conception has obtained such a firm hold on popular opinion that nearly all the recommendations as to improving the dietary referred to in the preceding chapters are, consciously or unconsciously, based on it—an addition to the nitrogenous principles of the diet being the prominent feature advocated. So long ago as 1845 it was maintained by Mayer that "a muscle is only an apparatus by means of which the transformation of force is effected, but that it itself is not the material by the change of which the mechanical work is produced." The correctness of this statement is now generally allowed, and further research has established that nearly all the motion, as well as the heat of the body, is dependent on the combustion within it of the carbonaceous principles of the food; whereas one of the chief uses of the nitrogenous principles is to serve as the pabulum from which the tissues are developed and renovated. The precise character of the changes which take place is still a disputed question; but it may serve as a help to the comprehension of this phase of the subject, even though the comparison be not scientifically accurate, were these living tissues of the body looked upon as the wick in the interstices of which* the products of carbonaceous material undergo chemical change—are in fact burnt—so as to set free the energy stored up in them. This change is incessantly taking place in the body in order to generate the heat and motion requisite for the maintenance of life, but, in order to withstand the influence of severe cold, or to perform extra labour, the process is accelerated. The more energetically this change proceeds the

* Whether in the cells of the tissue or in the lymph in which they are bathed, need not be specially considered here.

greater is the drain upon the assimilated carbonaceous [*i.e.*, starchy, saccharine and oleaginous] aliments; but the wick itself (to which for simplicity of illustration I have compared the living tissues) is not wasted by this extra combustion to anything like a corresponding extent. Even this waste, however, requires to be replaced as well as the used-up carbonaceous material, and there is an instinctive inclination to supply the general loss, but the food resorted to for the purpose depends very much on the habits of individuals.

74. No specially devised experiments appear to have been undertaken in this country with a view to ascertain the amount of food and the relative proportion in which the several alimentary principles should be given so as to ensure that they should be utilized in the animal economy to the best advantage. The only data available for the study of these points are those furnished by experiments which have been conducted in Europe and chiefly in the persons of well-to-do individuals accustomed to partake more or less largely of animal food, and consequently of a food richer in nitrogenous principles than that of the poorer classes in this country. The natural tendency of the teaching which is based on such experiments is to exaggerate the amount of albuminates necessary when considering the requirements of a population more vegetarian in its habits. It has been estimated that a dietary composed of some $4\frac{1}{2}$ ounces of dry albuminoid or nitrogenous food, of $14\frac{1}{4}$ ounces of carbo-hydrates (starch, sugar, etc.) and 3 ounces of fatty matters, is sufficient to maintain a European, of an average weight of 150 to 160 lbs., in good health whilst undergoing a fair amount of hard labour, and this scale has been suggested as a standard for general adoption. The nutritive value of such a diet, expressed in terms of nitrogen and carbon, is equal to about 316 grains of the former and 5,000 of the latter. It has, however, been ascertained that the poorer class of in-door labourers in England do not obtain anything like so much as this; and that the diet of the English soldier, when on home service, contains only 266 grains of nitrogen and 4,700 grains of carbon (Parkes). Moreover, Dr. Ranke, a well-known name in connection with the subject of dietetics, found that he could keep himself and do a fair amount of work on a diet containing 243 grains of nitrogen. His weight was $162\frac{1}{2}$ lbs.*

75. This is not the place to discuss in the abstract whether a diet, consisting largely or not at all of animal food, is the best for general adoption; nor does it fall within the province of this memorandum to consider the most suitable dietaries for training purposes or for the sick: the question is—what is the minimum amount of the most economical forms of food which experience has shown to be compatible with the exaction of a fair, average task-work, and at the same time to maintain native prisoners in health. The scales of diet of which the most accurate information can be

* The average weight of an English soldier may be taken as about 150 lbs., though this is probably a low estimate; hence, if 266 grains of nitrogen be sufficient for him, the proportion in a diet which should suffice for a person weighing 110 lbs. would be 195 grains; whilst, on a like computation based on Dr. Ranke's diet and weight, the amount of nitrogen would be 165 grains.

obtained, and which would seem to be most suitable to serve as standards for the construction of Indian jail dietaries, are those of the labouring prisoners in the convict and local jails of England. The diets which are in use in these two classes of prisons have, with trifling modifications, been in force for many years, and not only have they been reported upon most favourably by various Royal Commissions (some of the most recent of whose reports have been cited in a previous chapter), but the extremely favourable mortuary returns, extending over a long series of years, testify in the most unqualified manner to the general correctness of the opinions expressed by the Commissioners. Full details regarding these dietaries have already been given, but a summarized statement of the nutritive value of the principal forms may be reproduced here with advantage.

Nutritive value of the principal dietaries at present in force for labouring prisoners in English Jails.

Diet Scales.	Alimentary principles.			Nutritive value in grains.	
	Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.
Convict Prisons.	oz.	oz.	oz.		
1. Light labour	3·28	16·26	1·25	226	4,353
2. Industrial labour	3·53	17·09	1·47	243	4,648
3. Hard labour	3·82	18·53	1·52	263	5,013
Local Prisons.					
1. Hard labour : one to four months' imprisonment	3·13	16·22	1·02	215	4,232
2. „ „ over four months' imprisonment	3·91	19·67	1·37	270	5,204

76. The nutritive value of the maximum scales in force in the two classes of prisons is very nearly equal, but it is probable that, notwithstanding the slight inferiority of the maximum scale in Convict Prisons, as compared with that of the Local Prisons when estimated from chemical analyses, the dietary would be preferred by persons accustomed to animal food, seeing that it consists of an average daily allowance of 4½ oz. of meat, whereas the average of the daily allowance in Local Prisons is only about half this quantity—nitrogenous material in the latter case being made up by a correspondingly larger allowance of oatmeal and by an addition of peas to the dietary. Of the 270 grains of nitrogen contained in this scale, only 39 grains are derived from animal food. That rations containing so small an amount of meat should be associated with such favourable health statistics in a flesh-eating race, is worthy of notice, and especially so in that the dietary is found to be compatible with the exaction of even very hard labour. The proportion of the nitrogenous to the carbonaceous principles is much smaller than that contained in the ordinarily proposed

standard dietaries; but bearing in mind the respective parts played by these two alimentary principles in the production of muscular force, the satisfactory results are quite compatible with the present teaching of physiologists.* These results are, moreover, quite in accord with every-day experience in this country, where men are known to accomplish very great distances and bear a heavy burden on a dietary consisting of even a still greater disproportion between the albuminates and the carbo-hydrates, the amount of the former which is consumed being barely more than has been estimated to be actually necessary for the renovation of the tissues even when the body is at rest, whereas the amount of the starchy food consumed is often very large. In the formulæ for standard dietaries for Europeans, the proportion of the nitrogen to the carbon ordinarily recommended is as 1 to 15; but in the dietaries for labouring prisoners in English jails the proportion is about as 1 to 20: even this, however, is probably higher than the proportion in which the albuminates are found in the ordinary food of the poorer classes in this country, where the comparatively small amount of nitrogen present in the cheaper cereals has to be supplemented by the addition of the richer, and more expensive pulses. Seeing therefore that the labouring diet scales of the English Local Prisons approximate very closely to the food of natives in this country, especially as regards the proportion of it which is derived directly from the vegetable kingdom, and as this dietary has been found to be compatible with exceptionally favourable health returns, I have in a previous paragraph ventured to suggest that it should be adopted as a standard for the construction of Indian jail diets.

77. In adapting the scales of diet of any large body of men belonging to one country to like requirements in another, it is usual to take the average weight of the persons concerned as a leading basis for the computation, though, as has already been pointed out, it is essential that the comparative activity as well as the comparative physique of these persons should be prominently borne in mind—a small-built but exceptionally active race requiring, proportionately, more food, or at least more of that kind of food which serves as the ultimate source of energy, than a heavier but more indolent and apathetic one. In instituting a comparison, however, as to the capacity for physical exertion between English and Hindu workmen, there cannot be much doubt that the disproportion between the amount of work which the former can perform, compared with that of the latter, is probably quite as great as, if not greater than, the disproportion in their weights, so that taking weight alone as the basis for the calculation would not be to the disadvantage of the native. The average weight of the English prisoner has been assumed to be 145 lbs. and that of the Indian prisoner to be 110 lbs., though probably the mean weight has been somewhat understated in the former and somewhat overstated in the latter; but this

* Since this memorandum was in type, I have seen that Dr. Carpenter, the well-known writer on physiology, has recently contributed some articles to *Knowledge*, in which he appears to have drawn public attention to the importance of bearing this aspect of the diet-question more prominently in view than has hitherto been the case (vide *Saturday Review*, 19th November 1881).

probable margin of error will be in favour of the native prisoner as regards the quantity of food which would be accorded to him on a computation made on such a basis. According to such a computation the maximum daily allowance of water-free alimentary principles to persons of a mean weight of 110 lbs. would, in round numbers, be 3 oz. of albuminates, 15 oz. of carbo-hydrates, and 1 oz. of fat. A diet of this character would contain a little over 200 grains of nitrogen and a little less than 4,000 grains of carbon.

78. In the foregoing chapter the question as to how far labouring dietaries in Indian jails exceed or fall short of such a standard has been fully considered; and as it is difficult to summarize details of this kind with clearness, a tabular statement has been prepared of the nutritive value of the principal forms of the maximum labouring diets at present, or recently, in force in the various provinces. But, instead of repeating what has been said as to the extent of the variations from the above standard, the body-weight for which each scale should suffice has been added in a separate column. The calculation has been made on the assumption that the 270 grains of nitrogen contained in the maximum dietary of the English Local Prisons is sufficient for a labouring prisoner weighing 145 lbs. Nitrogen has been taken as the basis of the computation because, in the first place, a certain amount of nitrogenous substance is absolutely necessary in all foods and cannot be replaced by any other alimentary principle; and, secondly, because it is manifest that in a diet partaking so largely of vegetable substances, as does that of the bulk of the population of this country, it is not likely that a deficiency will occur in the carbonaceous principles provided the nitrogenous are adequately supplied.

The Nutritive Value of the principal Maximum Scales of Diet for Labouring Prisoners at present or recently in force in India; together with the weight of individuals for which each scale is estimated to be sufficient when computed on the English Local Prison standard, viz., 270 *grains of Nitrogen for a body-weight of* 145 *lbs.*

Serial No.	Maximum Diet Scales. [When meat and fish form separate diets, the meat scale has been taken.]	Alimentary Principles.			Nutritive Value in grains.		Weight of prisoner for whom the diet is estimated to suffice.	Serial No.
		Albuminates.	Carbo-hydrates.	Fats.	Nitrogen.	Carbon.		
	Indian Jail Committee of 1864—	oz.	oz.	oz.	grs.	grs.	lbs.	
1	(*a*) Scale adopted for Bengalis, Assamese, etc.* ...	2·97	18·98	1·11	205	4763	**110**	1
2	(*b*) Ditto adopted for Natives of Behar and Upper India*	3·63	19·11	1·24	251	4986	**134**	2
	Indian Jail Conference of 1877—							
3	(*a*) Rice form without animal food	2·85	21·66	0·51	197	5047	**105**	3
4	(*b*) Wheat form without animal food...	4·03	18·05	0·76	278	4707	**149**	4
5	(*c*) Rice form with animal food	3·03	19·89	0·68	209	4805	**112**	5
6	(*d*) Wheat form „ „	4·07	16·51	0·90	281	4165	**150**	6
7	Mean value of diets with 7 cereals—without animal food	3·22	18·66	1·10	223	4755	**119**	7
8	Mean value of diets with 7 cereals—with animal food	3·35	17·07	1·21	231	4513	**124**	8

* The average weight of adult *Bengali* prisoners is usually given as about 100 lbs.; and that of *Beharis* and Natives of Upper India generally, as about 110 lbs.

The Nutritive Value of the principal Maximum Scales of Diet for Labouring Prisoners at present or recently in force in India; together with the weight of individuals for which each scale is estimated to be sufficient when computed on the English Local Prison standard, viz., 270 *grains of Nitrogen for a body-weight of* 145 *lbs.*

Serial No.	Maximum Diet Scales. When meat and fish form separate diets, the meat scale has been taken.]	Alimentary Principles.			Nutritive Value in grains.		Weight of prisoner for whom the diet is estimated to suffice.	Serial No.
		Albuminates.	Carbohydrates.	Fats.	Nitrogen.	Carbon.		
	BENGAL—	oz.	oz.	oz.	grs.	grs.	lbs.	
9	(*a*) Form of "Conference" scales adopted for *Bengalis*—Rice without animal food	2·78	20·56	0·50	192	4814	**103**	9
10	(*b*) Ditto—Rice with animal food	2·91	19·22	0·63	201	4628	**107**	10
11	(*a*) Form of "Conference" scales adopted for *Beharis*—Wheat-and-rice without animal food ...	3·39	19·62	0·62	234	4814	**125**	11
12	(*b*) Ditto—Rice-and-wheat with animal food ...	3·52	18·27	0·75	243	4628	**130**	12
13	(*a*) *Present scales* for *Bengalis*—Rice without animal food (average)	3·82	24·23	0·84	264	5887	**141**	13
14	(*b*) Ditto—Rice with ditto (average)	3·57	22·99	1·00	247	5645	**132**	14
15	(*a*) *Present scales* for *Beharis*, etc. Rice-and-wheat without animal food	4·66	22·50	1·00	322	5802	**172**	15
16	(*b*) Ditto—Rice-and-wheat with animal food... ...	4·42	21·26	1·16	305	5560	**163**	16
17	Ditto—Average of 4 scales without animal food ...	4·35	23·58	1·26	301	6057	**161**	17
18	Ditto—Average of 4 scales with animal food... ...	4·11	22·47	1·42	284	5815	**152**	18
	ASSAM—							
19	(*a*) Scale for Assamese and Bengalis	3·23	18·65	1·00	223	4721	**119**	19
20	(*b*) Ditto for Beharis and Natives of Upper India ...	3·96	18·95	1·13	273	4994	**146**	20
	NORTH-WEST PROVINCES AND OUDH—							
21	Average value of standard diet scales	3·98	19·56	1·16	275	5128	**147**	21
22	Average value of diets issued in 1880 in 6 Central Jails	4·93	19·73	0·80	340	5257	**182**	22
23	Average value of diets issued in 1880 in 6 District Jails	4·45	20·00	0·69	307	5159	**164**	23
	PUNJAB—							
24	Average value of scales ordinarily in force	4·38	20·00	1·34	302	5374	**162**	24
25	Ditto in force from May to September	4·88	19·04	1·09	336	5212	**180**	25
26	Special scale for Rawal Pindi Jail	4·96	18·67	0·83	342	5070	**184**	26
27	Ditto for Rupar Jail	7·24	23·76	1·25	500	6771	**268**	27
	CENTRAL PROVINCES—							
28	The standard scale	4·56	20·91	1·51	315	5646	**169**	28
29	The reduced scale now very generally used	4·13	18·10	1·36	285	4949	**153**	29
	HYDERABAD ASSIGNED DISTRICTS—							
30	Scale in force up to October 1879	5·16	21·22	1·20	356	5738	**191**	30
31	The "Conference" scale in force from October 1879 to March 1881	3·53	19·15	1·04	244	4902	**131**	31
32	Scale now in force	4·05	20·22	1·32	280	5328	**150**	32
	MYSORE AND COORG—							
33	Scale for men of over two years' imprisonment ...	3·55	20·56	1·61	245	5376	**131**	33
	BRITISH BURMA—							
34	Mean value of maximum scales	2·55	19·87	0·94	176	4780	**94**	34
	ANDAMAN ISLANDS—							
35	Third-class and Chain-gang convicts' scales—Mean value	4·09	21·13	1·49	282	5575	**151**	35
36	Ditto when fish is not procurable	3·97	24·94	1·45	274	6275	**147**	36
	BOMBAY—							
37	Scale for the City Jail	3·03	15·57	0·81	209	4011	**112**	37
38	Scales for the other Jails, (*a*) average value without animal food	3·95	20·39	1·92	272	5544	**146**	38
39	Ditto—(*b*) Average value with ditto	3·39	17·69	2·27	234	5014	**125**	39
	MADRAS—							
40	Average value of scales for Central Jails	3·40	19·04	1·80	235	5113	**126**	40
41	Ditto for District and Subsidiary Jails	3·39	18·52	1·89	234	5037	**125**	41

79. It has already been pointed out that chemical analysis, however exhaustive, can only afford such information as will enable an approximate estimate to be formed of the nutritive value of any food, seeing that it is not only what nutriment a particular food stuff contains that is of moment, but also what portion of it can be readily digested and assimilated by the body. In a diet composed extensively of vegetable substances, the quality of the cooking is of much more importance than it is in animal food dietaries, seeing that a large proportion of nutriment contained in cereals and pulses is enclosed in extremely resistant, indigestible envelopes, which, if not effectually disposed of by proper cooking, defeat all attempts on the part of the digestive organs to profit by the food. In the endeavour which has been manifested by many framers of jail dietaries to raise the proportion of the nitrogenous element without necessitating a corresponding increase in the carbonaceous, a large addition to the pulses has been a favourite mode of meeting the requirements of a view which presupposed the rapid waste of muscle during exercise; but it is questionable whether so large an amount of nitrogenous material does not in reality deteriorate the value of the diet on account of the increased work thrown on the excretory organs in getting rid of a portion of the nitrogenous elements which the system does not require and which, to a certain extent, acts more as an irritant than as a food.* In some instances, however, the excess of the nitrogenous elements which is shown in many of the diet scales above tabulated, is given in the form of parched, and otherwise imperfectly cooked, gram, so that it is probable that a large proportion of the contained nutriment will not be assimilated. On several grounds therefore the addition of an undue proportion of pulses, and especially of ill-cooked pulses, is a doubtful advantage, and may be even injurious.

80. If the column giving the estimated weight of a person for which the several diet-scales should suffice be examined, it will be found that great variations are manifest. Whereas, for example, the maximum scale in force in British Burma has been computed as sufficing for the support of a mean body-weight of only 94 lbs., that in force in the Rupar Jail in the Punjab should suffice for a person weighing 268 lbs. The latter, however, is a special diet, the average value of the scales for the jails of the province generally, being for a body-weight of 162 to 180 lbs.

81. This tabular statement, however, does not appear to call for any lengthened explanation, but a brief reference to the data contained in it regarding the Bengal dietaries may serve as an illustration of the manner in which the table may be studied, and, also, show what appears to be the inference which a careful examination of the dietaries of English and Indian prisons suggests regarding the recent changes made in the Bengal scales. It will be seen that the value of the two maximum diet scales adopted by the Indian Jail Committee of 1864 has been estimated as sufficient, on the

* "A large meal of proteid material must tax the system to the utmost in getting rid of or stowing away the nitrogenous crystalline bodies arising through the luxus consumption either in the alimentary canal or in the liver." —*Text-book of Physiology* by M. Foster, F.R.S., Third Edition, page 442, 1879.

English Local Prison standard, for the maintenance of persons of an average weight of 110 and 134 lbs.—the former scale being for Bengalis and the latter for natives of Behar and of Upper India generally. These scales were in force in Bengal up to March 1879 when they were replaced by a dietary based on the recommendations of the Indian Jail Conference of 1877. According to the new regulations the issue of animal food, instead of being general to labouring prisoners, as had been the case heretofore, was restricted to such of them as had been accustomed to partake of it before their admission into jail. The difference in the aggregate nutritive value, however, of the dietaries, as judged from their chemical constituents, was not great, for the daily diets for Bengalis contained only from 4 to 13 grains less of nitrogen (with no material change in the carbon), and the scales should have sufficed for men weighing from 103 to 107 lbs.; whilst the scales for Beharis should have sufficed for men weighing from 125 to 130 lbs. Records of jail weighments show that neither Bengalis nor Beharis have an average weight equal to that for which even the minimum of their respective diet scales is estimated to provide. Nevertheless it was decided, after a year's trial, that the Conference dietary was wholly insufficient, and that it had, indeed, contributed materially to the death rate amongst the prisoners. New scales for Bengalis and for Beharis were introduced last July, and are now in force. The table shows that the present scales for Bengalis should suffice for prisoners weighing from 132 to 141 lbs., and the Behari scales for men weighing from 152 to 172 lbs. If the issue of the Conference rations was efficiently supervised and the cooking properly conducted, it is difficult to reconcile the recorded experience of Bengal with that which is furnished by, for example, the jails of Burma. Here, with a maximum labouring diet scale which, calculated on a like basis, should suffice for men weighing only 94 lbs.—and which, moreover, has been in force for several years—the mortality for some time past has been lower than it has been in any province in India; and where, during 1880, out of a total of 6,971 prisoners who were weighed, 5,206 were found to have gained since their admission into jail. In Burma, therefore, a maximum diet containing 176 grains of nitrogen and 4,780 of carbon has been found compatible with exceptionally favourable mortuary returns; whereas in Bengal, a prison population, closely similar as regards habits and physique, is considered to have been partially starved on even a minimum scale of diet containing 192 grains of nitrogen and 4,814 grains of carbon—rice having formed the staple cereal in both provinces.

82. In the tabular statements appended to this memorandum, the nutritive value of 151 scales of Indian Jail diets for labouring prisoners has been computed. Of these, nominally only 86 are actually in force at the present time, and several are but modifications of the same scales adapted to prisoners of varying length of sentences. In reality, however, the number of dietaries is considerably greater than the above figures imply, as some latitude is necessarily allowed to local officials as regards the selection of such grains and pulses as are most readily obtainable in their particular districts, and at different seasons of the year. One kind of grain is, consequently, frequently

replaced by another, and, in the absence of any fixed rule, the nutritive value of the rations actually issued to the prisoners varies even to a greater extent than these tables indicate. It is therefore very desirable that some general principle should be adopted as regards the quantities of the several grains and pulses which should be used, as, even judged from their chemical composition alone, they are far from being of equivalent value and cannot be issued measure for measure. Were satisfactory information obtained from officers practically conversant with the dieting of large bodies of men as to the value which should be attached to these several food-stuffs, in addition to what we know of their chemical composition, and as to the most satisfactory manner of cooking them, the difficulty of preparing scales of diets suitable for the several provinces would be very materially diminished and dietaries could be devised in which the nutritive values would not present such extreme discrepancies as are now manifested even in the standard scales.

83. So far as our knowledge of these matters permits of an opinion being formed, it would seem that the dietaries which have been in force in India during recent years, have not been insufficient. Indeed, an examination of the tabular statement above given shows that native labouring prisoners in every province in India have been, weight for weight, better fed than either convict or other prisoners in England. In British Burma the maximum diet is lower, but only as regards the nitrogenous elements, and, even in this respect, Burmese prisoners receive proportionately a larger quantity than Dr. Ranke (who was not a vegetarian) found was enough to maintain himself in health whilst performing a moderate amount of work. It has been shown in the preceding chapter that the lowest scales are by no means associated with the most unfavourable health-returns, but that, on the contrary, in those instances where enquiry has been especially made, the results in this respect were even better than those associated with the most liberal diet scales, though this, of course, may be a mere coincidence. When the scales of diets are calculated so as to be just sufficient for the maintenance of labouring communities in health and no more, it goes without saying that the most stringent measures should be adopted that the quality of the staple articles of food and notably of the fresh vegetables is unexceptionable, and that the cooking and the issue of the rations should be most closely supervised. The fulfilment of some such conditions as these is absolutely essential to the success of any scale of diet. It is believed that they are strictly carried out in English prisons; and were the penalties of non-fulfilment sufficiently severe in Indian jails, there does not appear to be any reason why scales of diet for native prisoners framed, as already indicated, on the basis of those diets which have proved so successful in England, should not prove equally successful in this country.

84. As above stated (para. 77), the proportion of the alimentary principles contained in the maximum diet scale of English Local Prisons, which should suffice for persons of an average weight of 110 lbs., amounts to about 3 oz. of albuminates, 15 oz. of carbo-hydrates, and 1 oz. of fats. In such a diet the proportion of carbo-hydrates

to the albuminates is as five to one, but observation of the ordinary habits of natives, as well as a study of such jail diets as have proved successful, suggests the advisability of the proportion being as six or six and a half to one when the dietary consists exclusively, or almost exclusively, of vegetable substances. Moreover, a diet in which the several alimentary principles are distributed in such proportions would seem to be in accord with the teachings of modern physiologists as to the respective parts which they play in the economy. The aggregate of the fatty matter should not be less than 1 oz. per diem, and this amount might be increased with advantage to $1\frac{1}{2}$ oz. during the colder season of the year, as a considerable proportion of the food which in warm weather goes towards the production of mechanical power is in cold weather diverted to meet the extra calls upon the system to maintain the heat of the body at its healthy standard. This suggestion is based on the fact that the inhabitants of cold countries resort largely to fatty food as a means of resisting the influence of cold, and is made quite apart from theoretical considerations as to the principal sources of the heat of the body, regarding which much uncertainty prevails.

The diet above sketched would, therefore, in round numbers, consist of the following proportions of water-free principles: albuminates 3 oz., carbo-hydrates 18 to 19 oz., and fats 1 to $1\frac{1}{2}$ oz.; while its value, expressed in terms of nitrogen and carbon, would be 207 grains of the former and from 4,500 to nearly 5,000 grains of the latter. The half-an-ounce of common salt, which is very generally issued in Indian as well as in English prisons, appears to be enough. Judging from the data which have been collected during the preparation of this memorandum, a diet of this character should, if properly cooked, be sufficient to maintain native prisoners, of an average weight of 110 lbs., in good health, and at the same time be compatible with the exaction of a fair amount of ordinary hard labour.

SIMLA,
November 1881.

[Tabular Statements of the several Diet Scales and of their Nutritive Values in terms of Nitrogen and Carbon are appended; as also of the Factors adopted in the computations.]

Factors adopted in computing the Nutritive Values of the several ingredients entering into English and Indian Jail Diets.

[The data given in Dr. Parkes' *Manual of Hygiene* (5th Edition) have been resorted to except when otherwise mentioned.]

	Grains per Ounce.		Percentage of Fats.
	Nitrogen.	Carbon.	
Cereals in Indian diets :—			
Wheat, Gahun (*Triticum Vulgare*)	9·22*	170*	2·0
Barley, Jow (*Hordeum vulgare*)	5·81*		1·8
Rice, Chawul (*Oryza sativa*)	5·07*		0·8
Bajra, Cumboo, spiked millet (*Penicillaria spicata*)	7·00		4·6
Jowar Cholum (*Sorghum* or *Panicum vulgare*)	5·97		3·9
Maize, Mukka (*Zea mais*)	6·93		6·7
Ragi, Murwa (*Eleusine corocana*), calculated as common millet ...	6·40		5·0
Pulses or *Dhâls* in Indian diets—Average values	17·86*		1·5†
Uncooked meat, meat for soup, &c.	10·35	64·0	8·4
Cooked meat	19·0	117·7	15·45
Fish (white)	11·5	52·4	2·9
Fats and Oils	...	345·6	...
Milk	2·75	30·8	3·7
Bread	5·5	119	1·5
Oatmeal	8·7	172	5·6
Flour (English) for puddings	7·6	169	2·0
Suet (Letheby)	...	294·3	85·1
Cheese	23·0	162	24·3
Peas	15·0	161	2·0
Pearl Barley	4·3	167·2	2·4
Potatoes	1·0	49	0·1
Succulent vegetables [mean value of carrots and potatoes (Parkes) adopted by Lyon]	0·70	33·5	0·17
Onions (Church)	1·0	13·5	0·2
Sub-acid fruits [Tamarind, &c.]—Mean of analysis of five kinds (Dobell)	5·7	17·5	...
Cocoa (Pavy)	11·0	188·3	19·0
Molasses (Letheby)	...	149·5	...

* Dr. Lyon.—See paras. 29 and 30 of Memorandum.
† Average of several pulses.

TABLE I.

Dietaries approved by the INDIAN JAIL COMMITTEE *of* 1864 *for Labouring and Under-Trial Prisoners, together with their Nutritive values.*

[These appear to have been in force in Lower Bengal from 1860 to 1879.]

Nationalities.	Ingredients entering into the several Diets.	Labouring and Under-Trial Prisoners. (a) Meat Column. Ounces. On 4 days.	(a) Meat Column. Ounces. On 3 days.	(a) Meat Column. Ounces. Total for the week.	(a) Meat Column. Nutritive value in grains. Nitrogen.	(a) Meat Column. Nutritive value in grains. Carbon.	(b) Fish Column. Ounces. On 4 days.	(b) Fish Column. Ounces. On 3 days.	(b) Fish Column. Ounces. Total for the week.	(b) Fish Column. Nutritive value in grains. Nitrogen.	(b) Fish Column. Nutritive value in grains. Carbon.	Serial number.
Bengalis, Uryas and Assamese.	I.											
	1. Rice	20·5*	20·5	143·5	727·5	24,395·0	20·5	20·5	143·5	727·5	24,395·0	1
	2. Meat	4·1	...	16·4	169·7	1,049·6	...	...	...	...	...	2
	3. Fish	...	...	...	...	...	4·1	...	16·4	188·6	859·3	3
	4. Pulse	4·1	4·1	28·7	512·5	4,879·0	4·1	4·1	28·7	512·5	4,879·0	4
	5. Vegetables ...	4·1	8·2	41·0	28·7	1,373·5	4·1	8·2	41·0	28·7	1,373·5	5
	6. Oil	0·68	0·68	4·76	...	1,645·0	0·68	0·68	4·76	...	1,645·0	6
	7. Salt	0·5	0·5	3·5	...	...	0·5	0·5	3·5	...	...	7
	8. Condiments ...	0·5	0·5	3·5	...	...	0·5	0·5	3·5	...	...	8
	Average daily Nutritive Value =				205	4,763	...	...	...	208	4,736	
Natives of Behar, N.-W. P. and the Punjab.	II.											
	1. Rice	12·3	12·3	86·1	436·5	14,637·0	12·3	12·3	86·1	436·5	14,637·0	1
	2. Attah (wheaten flour)	10·2	10·2	71·4	658·3	12,138·0	10·2	10·2	71·4	658·3	12,138·0	2
	3. Meat	4·1	...	16·4	169·7	1,049·6	...	...	...	...	...	3
	4. Fish	...	...	...	...	...	4·1	...	16·4	188·6	859·3	4
	5. Pulse	2·0	6·1	26·3	469·7	4,471·0	2·0	6·1	26·3	469·7	4,471·0	5
	6. Vegetable	4·1	4·1	28·7	20·0	961·4	4·1	4·1	28·7	20·0	961·4	6
	7. Oil	0·68	0·68	4·76	...	1,645·0	0·68	0·68	4·76	...	1,645·0	7
	8. Salt...	0·6	0·6	4·2	...	...	0·6	0·6	4·2	...	...	8
	9. Condiments ...	0·5	0·5	3·5	...	...	0·5	0·5	3·5	...	...	9
	Average daily Nutritive Value =				251	4,986	...	...	...	253	4,959	

* Ten *chittacks* [One chittack = 2·05 oz. avoirdupois].

TABLE II.

Some of the Principal forms into which the diet scale for Native Labouring Prisoners proposed by the INDIAN JAIL CONFERENCE *of* 1877 *may be resolved.*

Number.	Ingredients entering into the several Diets.	(*a*) Diets consisting solely of Vegetable and Fatty Substances.			ANIMAL FOOD FORMS OF DIET—OPTIONAL.										
					(*b*) Meat.					(*c*) Fish.					
			Nutritive value in grains.		Ounces.			Nutritive value in grains.		Ounces.			Nutritive value in grains.		
		Ounces.	Nitrogen.	Carbon.	On 4 days.	On 3 days.	Total weekly.	Nitrogen.	Carbon.	On 4 days.	On 3 days.	Total weekly.	Nitrogen.	Carbon.	
I	Rice	24	121·6	4080·0	20	24	152	770·6	25,840	20	24	1·52	770·6	25,840	
	Meat	...	...	...	4	...	16	165·6	1,024	...	...	...	...	...	
	Fish	...	...	...	...	...	...	...	...	4	...	16	184	838	
	Pulse	4	71·4	680·0	4	4	28	500	4,760	4	4	28	500	4,760	
	Vegetable	6	4·2	201	6	6	42	29·4	1,407	6	6	42	29·4	1.407	
	Fat	·25	...	86·4	·25	·25	1·75	...	604	·25	·25	1·75	...	604	
	Salt	·5	...	...	·5	·5	3·5	...	...	·5	·5	3·5	...	...	
	Condiments	·25	...	..	·25	·25	1·75	...	...	·25	·25	1·75	...	...	
	Average daily Nutritive value ...		**197**	**5,047**	...	...	...	**209**	**4,805**	...	...	...	**213**	**4,778**	
II	Wheat Flour	22	202·8	3,740	18	22	138	1,272·3	23,460	18	22	138	1272·3	23,460	
	Other Ingredients	11	75·6	967·4	15	11	93	695	7,795	15	11	93	713·4	7,609	
	Average daily Nutritive value ...		**278**	**4,707**	...	...	...	**281**	**4,465**	...	...	...	**284**	**4,438**	
III	Barley Flour	22	127·8	3,740	18	22	138	801·7	23,460	18	22	138	801·7	23,460	
	Other Ingredients	11	75·6	967·4	15	11	93	695	7,795	15	11	93	713·4	7,609	
	Average daily Nutritive value ...		**203**	**4,707**	...	...	...	**214**	**4,465**	...	...	...	**216**	**4,438**	
IV	Jowar Flour	22	131·3	3,740	18	22	138	823·8	23,460	18	22	138	823·8	23,460	
	Other Ingredients	11	75·6	967·4	15	11	93	695	7,795	15	11	93	713·4	7,609	
	Average daily Nutritive value ...		**207**	**4,707**	...	...	...	**217**	**4,465**	...	...	...	**220**	**4,438**	
V	Bajra Flour	22	154	3,740	18	22	138	966	23,460	18	22	138	966	23,460	
	Other Ingredients	11	75·6	967·4	15	11	93	695	7,795	15	11	93	713·4	7,609	
	Average daily Nutritive value ...		**230**	**4,707**	...	...	...	**237**	**4,465**	...	...	...	**240**	**4,438**	
VI	Makki Flour (Maize) ...	22	152·4	3,740	18	22	138	956·3	23,460	18	22	138	956·3	23,460	
	Other Ingredients	11	75·6	967·4	15	11	93	695	7,795	15	11	93	713·4	7,609	
	Average daily Nutritive value ...		**228**	**4,707**	...	...	...	**236**	**4,465**	...	...	...	**238**	**4,438**	
VII	Ragi Flour (Millet)	22	140·8	3,740	18	22	138	883·2	23,460	18	22	138	883·2	23,460	
	Other Ingredients	11	75·6	967·4	15	11	93	695	7,795	15	11	93	713·4	7,609	
	Average daily Nutritive value ...		**216**	**4,707**	...	...	...	**225**	**4,465**	...	...	...	**228**	**4,438**	

TABLE III.

The scales of Diet for Labouring Prisoners in force in LOWER BENGAL *between March* 1879 *and March* 1880, *and their average daily Nutritive values.*

Nationalities.	Ingredients entering into the several Diets.	(*a*) Diets consisting solely of vegetable substances.			Diets (optional) containing animal food.									Serial Number.
					(*b*) Meat.					(*c*) Fish.				
			Nutritive value in grains.		Ounces.			Nutritive value in grains.		Ounces.			Nutritive value in grains.		
		Ounces daily.	Nitrogen.	Carbon.	On 4 days.	On 3 days.	Total for the week.	Nitrogen.	Carbon.	On 4 days.	On 3 days.	Total for the week.	Nitrogen.	Carbon.	
Bengal and Uryas.	I.														I.
	1. Rice	22·5	114·0	3,825·0	22·5	18·4	145·2	736·1	24,684·0	22·5	18·4	145·2	736·1	24·684·0	1
	2. Meat	...	...	...	...	4·1	12·3	127·3	787·2	...	...	...	...	...	2
	3. Fish	...	...	...	...	...	...	...	...	...	4·1	12·3	141·4	644·5	3
	4. Pulse	4·1	73·2	697·0	4·1	4·1	28·7	512·5	4,879·0	4·1	4·1	28·7	512·5	4,879·0	4
	5. Vegetables	6·15	4·3	206·0	6·15	6·15	43·0	30·1	1,440·5	6·15	6·15	43·0	30·1	1,440·5	5
	6. Oil	0·25	...	86·4	0·25	0·25	1·75	...	604·8	0·25	0·25	1·75	...	604·8	6
	7. Salt	0·51	...	...	0·51	0·51	3·57	...	...	0·51	0·51	3·57	...	...	7
	8. Condiments	0·25	...	...	0·25	0·25	1·75	...	...	0·25	0·25	1·75	...	...	8
	Daily average Nutritive value= ...		**192**	**4,814**	...	...	...	**201**	**4,628**	...	...	...	**203**	**4,607**	...
Natives of Behar, North-Western Provinces and Punjab.	II.														II.
	1. Rice	12·3	62·3	2,091	12·3	8·2	73·8	374·1	12,546	12·3	8·2	73·8	374·1	12,546	1
	2. Wheat Flour	10·2	94·0	1,734	10·2	10·2	71·4	658·3	12,138	10·2	10·2	71·4	658·3	12,138	2
	3. Meat	...	...	...	...	4·1	12·3	127·3	787·2	...	...	...	...	...	3
	4. Fish	...	...	...	...	...	...	...	...	...	4·1	12·3	141·4	644·5	4
	5. Pulse	4·1	73·2	697	4·1	4·1	28·7	512·5	4,879·0	4·1	4·1	28·7	512·5	4,879·5	5
	6 Vegetables	6·15	4·3	206	6·15	6·15	43·0	30·1	1,440·5	6·15	6·15	43·0	30·1	1,440·5	6
	2. Oil	0·25	...	86·4	0·25	0·25	1·75	...	604·8	0·25	0·25	1·75	...	604·8	7
	8. Salt	0·51	...	...	0·51	0·51	3·57	...	...	0·51	0·51	3·57	...	...	8
	9. Condiments	0·25	...	...	0·25	0·25	1·75	...	...	0·25	0·25	1·75	...	...	9
	Daily average Nutritive value= ...		**234**	**4,814**	...	...	...	**243**	**4,628**	...	...	...	**245**	**4,607**	...
	III.														III.
	1. Rice	12·3	62·3	2,091	12·3	8·2	73·8	374·1	12,546	12·3	8·2	73·8	374·1	12,546	1
	2. Maize Flour	12·3	85·2	2,091	12·3	12·3	86·1	596·6	14,637	12·3	12·3	86·1	596·6	14,637	2
	3. Meat	...	...	...	...	4·1	12·3	127·3	787·2	...	...	...	...	...	3
	4. Fish	...	...	...	...	...	...	...	...	...	4·1	12·3	141·4	644·5	4
	5—9. Of No. II.	11·26	77·5	989·4	11·26	11·26	78·82	542·6	6,924·3	11·26	11·26	78·82	542·6	6,924·3	5—9
	Daily average Nutritive value = ...		**225**	**5,171**	...	...	...	**234**	**4,985**	...	...	...	**236**	**4,964**	...
	IV.														IV.
	1. Rice	12·3	62·3	2,091	12·3	8·2	73·8	374·1	12,546	12·3	8·2	73·8	374·1	12,546	1
	2. Millet Flour	12·3	78·7	2,091	12·3	12·3	86·1	551·0	14,637	12·3	12·3	86·1	551·0	14,637	2
	3. Meat	...	...	...	...	4·1	12·3	127·3	787·2	...	...	...	...	...	3
	4. Fish	...	...	...	...	...	...	...	...	...	4·1	12·3	141·4	644·5	4
	5—9. Of No. II.	11·26	77·5	989·4	11·26	11·26	78·82	542·6	6,924·3	11·26	11·26	78·82	542·2	6,924·3	5—9
	Daily average Nutritive value = ...		**218**	**5,171**	...	...	...	**228**	**4,985**	...	...	...	**230**	**4,964**	...

TABLE IV.

The scales of Diet for Labouring Prisoners adopted in LOWER BENGAL *in July* 1881, *and their average daily Nutritive values.*

Nationalities.	Ingredients entering into the several Diets.	Diets consisting solely of vegetable substances.			Diets (optional) containing animal food.										Serial Number.
					Meat.					Fish.					
			Nutritive value in grains.		Ounces.			Nutritive value in grains.		Ounces.			Nutritive value in grains.		
		Ounces daily.	Nitrogen.	Carbon.	On 4 days.	On 3 days.	Total for the week.	Nitrogen.	Carbon.	On 4 days.	On 3 days.	Total for the week.	Nitrogen.	Carbon.	
For Bengalis and Uryas.	I.														
	1. Rice	22	111·5	3,740·0	22	22	154·0	780·7	26,180·0	22	22	154·0	780·7	26,280·0	1
	2. Meat	...	...	...	4	...	16·0	165·6	1,024·0	...	...	...	...	...	2
	3. Fish	...	...	...	...	...	...	...	...	4	...	16·0	184·0	838·4	3
	4. Pulse	6	107·1	1,020·0	2	6	26·0	464·3	4,420·0	2	6	26·0	464·3	4,420·0	4
	5. Vegetables	6	4·2	201·0	6	6	42·0	29·4	1,407·0	6	6	42·0	29·4	1,407·0	5
	6. Oil	·5	...	172·8	·5	·5	3·5	...	1,209·6	·5	·5	3·5	...	1,209·6	6
	7. Tamarind	·5	4·3	8·7	·5	·5	3·5	30·6	61·2	·5	·5	3·5	30·6	61·2	7
	8. Salt	·5	...	...	·5	·5	3·5	...	...	·5	·5	3·5	...	...	8
	9. Condiments	·25	...	...	·25	·25	1·75	...	...	·25	·25	1·75	...	...	9
	10. Molasses	1	...	149·6	1	·1	7·0	...	1,047·2	1	1	7·0	...	1,047·2	10
	11. Gram *	3	53·5	510·0	3	·3	21·0	375·0	3,570·0	3	3	21·0	375·0	3,570·0	11
	Daily average Nutritive value =		**281**	**5,802**	...	...	...	**264**	**5,560**	...	...	...	**266**	**5,533**	...
	II.														
	1—10. As in No. I	36·75	227·1	5,292·1	36·75	36·75	257·25	1,470·6	35,349·0	36·75	36·75	257·25	1,489·0	35,163·4	...
	11. Rice *	4	20·2	680·0	4	4	28·0	141·9	4,760·0	4	4	28	141·9	4,760·0	...
	Daily average Nutritive value =		**247**	**5,972**	...	...	...	**230**	**5,730**	...	...	...	**233**	**5,703**	...
For Natives of Behar, North-Western Provinces and Punjab.	III.														
	1. Rice	12	60·8	2,040·0	12	12	84·0	425·8	14,280·0	12	12	84·0	425·8	14,280·0	1
	2. Wheat Flour	10	92·2	1,700·0	10	10	70·0	645·4	11,900·0	10	10	70·0	645·4	11,900·0	2
	3. Meat	...	...	...	4	...	16·0	165·6	1,024·0	...	...	...	...	...	3
	4. Fish	...	...	...	...	...	...	...	...	4	...	16·0	184·0	838·4	4
	5. Pulse	6	107·1	1,020·0	2	6	26·0	464·3	4,420·0	2	6	26·0	464·3	4,420·0	5
	6. Vegetables	6	4·2	201·0	6	6	42·0	29·4	1,407·0	6	6	42·0	29·4	1,407·0	6
	7. Oil	·5	...	172·8	·5	·5	3·5	...	1,209·6	·5	·5	3·5	...	1,209·6	7
	8. Tamarind	·5	4·3	8·7	·5	·5	3·5	30·6	61·2	·5	·5	3·5	30·6	61·2	8
	9. Salt	·5	...	...	·5	·5	3·5	...	...	·5	·5	3·5	...	...	9
	10. Condiments	·25	...	...	·25	·25	1·75	...	...	·25	·25	1·75	...	...	10
	11. Molasses	1	...	149·6	1	1	7·0	...	1,047·2	1	1	7·0	...	1,047·2	11
	12. Gram *	3	53·5	510·0	3	3	21·0	375·0	3,570·0	3	3	21·0	375·0	3,570·0	12
	Daily average Nutritive value =		**322**	**5,892**	...	...	...	**305**	**5,560**	...	...	...	**308**	**5,533**	...
	IV.														
	1—11. As in No. III.	36·75	268·6	5,292·1	36·75	36·75	257·25	1,761·1	35,349·0	36·75	36·75	257·25	1,779·5	35,163·4	...
	12. Rice *	4	20·2	680·0	4	4	28	141·9	4,760·0	4	4	28	141·9	4,760·0	...
	Daily average Nutritive value =		**289**	**5,972**	...	...	...	**272**	**5,730**	...	...	...	**274**	**5,703**	...
	V.														
	1. Rice	12	60·8	2,040·0	12	12	84·0	425·8	14,280·0	12	12	84·0	425·8	14,280·0	...
	2. Maize	12	83·1	2,040·0	12	12	84·0	582·1	14,280·0	12	12	84·0	582·1	14,280·0	...
	3—12. As in No. III.	17·75	169·1	2,062·1	17·75	17·75	124·2	1,064·9	12,739·0	17·75	17·75	124·2	1,083·3	12,553·4	...
	Daily average Nutritive value =		**313**	**6,142**	...	...	...	**296**	**5,900**	...	...	...	**299**	**5,873**	...
	VI.														
	1. Rice	12	60·8	2,040·0	12	12	84·0	425·8	14,280·0	12	12	84·0	425·8	14,280·0	...
	2. Maize	12	83·1	2,040·0	12	12	84·0	582·1	14,280·0	12	12	84·0	582·1	14,280·0	...
	3—11. As in No. III.	14·75	115·6	1,552·1	14·75	14·75	103·25	689·9	9,169·0	14·75	14·75	103·25	708·3	8,983·4	...
	12. Rice *	4	20·2	680·0	4	4	28·0	141·9	4,760·0	4	4	28·0	141·9	4,760·0	...
	Daily average Nutritive value =		**280**	**6,312**	...	...	...	**262**	**6,070**	...	...	...	**265**	**6,043**	...

* As a morning meal.

TABLE V.

The scales of Diet in force in ASSAM *for Labouring Prisoners with their Nutritive values.*

Ingredients entering into the several forms of diet.	For Bengalis and Assamese.			For Natives of Behar, N.-W. P. and Punjab.			Serial number.
	Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		
		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. Wheat flour	...	...	...	10	92·2	1,700	1
2. Rice	20	101·4	3,400	12	60·8	2,040	2
3. Fish*	4	46·0	209·6	4	46	209·6	3
4. Pulse	4	71·4	680	4	71·4	580	4
5. Vegetables	6	4·2	201	4	2·8	134	5
6. Fatty matter	·66	...	230·4	·66	...	230·4	6
7. Salt	·5	...	...	·5	...	...	7
8. Condiments	·5	...	...	·5	...	...	8
Average daily Nutritive value =		**223**	**4,721**	...	**273**	**4,994**	

* Or an equivalent of milk.

TABLE VI.

Scales of Diet for Labouring Prisoners in the NORTH-WESTERN PROVINCES *and* OUDE *Jails.*

Class.	Ingredients entering into the several diets.	Ounces daily.	Principal cereals and combinations of them.														Serial Number.
			I. Wheat.		II. Bajra.		III. Maize.		IV. Jowar.		V. Wheat and Barley.		VI. Bajra and Maize.		VII. Jowar and Bajra.		VIII. Jowar and Maize.		
			Nutritive value in grains.		Nutritive value in grains.		Nutritive value in grains.		Nutritive value in grains.		Nutritive value in grains.		Nutritive value in grains.		Nutritive value in grains.		Nutritive value in grains.		
			Nitrogen.	Carbon.	Nitrogen.	Carbon.	Nitrogen.	Carbon.	Nitrogen.	Carbon.	Nitrogen.	Carbon.	Nitrogen.	Carbon.	Nitrogen.	Carbon.	Nitrogen.	Carbon.	
3 months and under.	1. Cereal flour ...	22·8	210·2	3,876·0	159·6	3,876·0	158·0	3,876·0	136·1	3,876·0	171·3	3,876·0	158·8	3,876·0	147·8	3,876·0	147·0	3,876·0	1
	2. Pulse	1·1	19·6	187·0	19·6	187·0	19·6	187·0	19·6	187·0	19·6	187·0	19·6	187·0	19·6	187·0	19·6	187·0	2
	3. Vegetables ...	5·1	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3
	4. Oil or Ghee ...	0·08	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	4
	5. Salt	0·22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5
	6. Chillies ...	1 pod	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6
	Daily average Nutritive value ... ... =		**233**	**4,261**	**183**	**4,261**	**181**	**4,261**	**159**	**4,261**	**194**	**4,261**	**182**	**4,261**	**171**	**4,261**	**170**	**4,261**	
Over 3 months.	1. Cereal Flour ...	22·8	210·2	3,876·0	159·6	3,876·0	158·0	3,876·0	136·1	3,876·0	171·3	3,876·0	158·8	3,876·0	147·8	3,876·0	147·0	3,876·0	1
	2. Pulse	6·2	110·7	1,054·0	110·7	1,054·0	110·7	1,054·0	110·7	1,054·0	110·7	1,054·0	110·7	1,054·0	110·7	1,054·0	110·7	1,054·0	2
	3. Vegetables ...	5·1	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3·5	170·8	3
	4. Oil or Ghee ...	0·08	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	...	27·6	4
	5. Salt	0·22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5
	6. Chillies ...	1 pod	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6
	Daily average Nutritive value ... ... =		**324**	**5,128**	**274**	**5,128**	**272**	**5,128**	**250**	**5,128**	**285**	**5,128**	**273**	**5,128**	**262**	**5,128**	**261**	**5,128**	

TABLE VII.

Average daily Nutritive value of the Diets actually issued to Labouring Prisoners during 1880 *in six* DISTRICT *Jails in the* NORTH-WESTERN PROVINCES *and* OUDH.

INGREDIENTS ENTERING INTO THE SEVERAL DIETS.	ALLAHABAD.							BAREILLY.							BENARES.							Serial Number.
	Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						
		3 months and under.			Over 3 months.				3 months and under.			Over 3 months.				3 months and under.			Over 3 months.			
		Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.			Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.			Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.		
			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.	
I.																						I.
. Cereal flour—																						1.
a.—*Wheat* ...	6,933·2	19·1	176·1	3,247·0	19·1	176·1	3,247·0	4,286·4	11·7	107·8	1,989·0	11·7	107·8	1,989·0	2,081·7	5·7	52·5	969·0	5·7	52·5	969·0	a.
b.—*Bajra* ...	147·6	0·4	2·8	68·0	0·4	2·8	68·0	...	...	...	...	...	...	...	343·2	0·9	6·3	153·0	0·9	6·3	153·0	b.
c.—*Maize* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	c.
d.—*Jowar* ...	...	...	...	...	...	...	...	1,710·0	4·7	28·0	799·0	4·7	28·0	799·0	1,043·9	2·9	17·3	493·0	2·9	17·3	493·0	d.
e.—*Barley* ...	623·2	1·7	9·8	289·0	1·7	9·8	289·0	1,789·8	4·9	28·4	833·0	4·9	28·4	833·0	5,244·6	14·3	83·0	2,431·0	14·3	83·0	2,431·0	e.
f.—*Gram** ...	623·2	1·7	30·3	289·0	1·7	30·3	289·0	558·6	1·5	26·7	255·0	1·5	26·7	255·0	...	...	.	...	...	...	...	f.
2. Pulse	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	2.
8. Vegetables ...	...	5·1	3·5	170·8	5·1	3·5	170·8	...	5·1	3·5	170·8	5·1	3·5	170·8	...	5·1	3·5	170·8	5·1	3·5	170·8	3.
4. Oil or ghee ...	...	0·08	...	27·6	0·08	...	27·6	...	0·08	...	27·6	0·08	...	27·6	...	0·08	...	27·6	0·08	...	27·6	4.
5. Salt	...	0·22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.
6. Chillies	...	1 pod	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.
Average daily nutritive value } =			242	4,278	...	333	5,145	*Average daily nutritive value*		214	4,261	...	305	5,128	*Average daily nutritive value*		182	4,431	...	273	5,298	...

Ingredients entering into the several Diets.	Meerut.							Moradabad.							Rai Bareilly.							Serial Number.
	Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets, of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets, of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets, of Labouring Prisoners.						
		3 months and under.			Over 3 months.				3 months and under.			Over 3 months.				3 months and under.			Over 3 months.			
		Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.			Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.			Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.		
			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.	
I.																						
1. Cereal flour—																						1.
a.—*Wheat* ...	6,167·4	16·8	154·8	2,856·0	16·8	154·8	2,856·0	3·995·7	10·9	100·4	1,853·0	10·9	100·4	1,853·0	2,006·4	5·5	50·7	935·0	5·5	50·7	935·0	a.
b.—*Bajra* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	b.
c.—*Maize* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	c.
d.—*Jowar* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	1,938·0	5·3	31·6	901·0	5·3	31·6	901·0	d.
e.—*Barley* ...	136·8	0·4	2·3	68·0	0·4	2·3	68·0	4,349·1	11·9	69·1	2·023·0	11·9	69·1	2,023·0	4,012·8	10·9	63·3	1,853·0	10·9	63·3	1,853·9	e.
f.—*Gram** ...	2,040·6	5·6	100·0	952·0	5·6	100·0	952·0	...	...	...	...	...	...	...	387·6	1·1	19·6	187·0	1·1	19·6	187·0	f.
2. Pulse	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	2.
3. Vegetables ...	...	5·1	3·5	170·8	5·1	3·5	170·8	...	5·1	3·5	170·8	5·1	3·5	170·8	...	5·1	3·5	170·8	5·1	3·5	170·8	3.
4. Oil or ghee ...	...	0·08	...	27·6	0·08	...	27·6	...	0·08	...	27·6	0·08	...	27·6	...	0·08	...	27·6	0·08	...	27·6	4.
5. Salt	...	0·22	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	5.
6. Chillies	...	1 pod	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	6.
Average daily nutritive value =		280	4,261		371	5,128		*Average daily nutritive value*	193	4,261		284	5,128		*Average daily nutritive value*	188	4,261		279	5,128		

* To avoid confusion *Gram* and *Urd* have been tabulated amongst the cereals, as they have been issued instead of staple cereal. The calculation, however, has been carried out as for other pulses except as regards the fatty matter contained in Gram, which has been taken as 3·7 per cent.

The amount of Fatty Substances in each of the above Diet Scales:—

Jail.	Under 3 months.	Over 3 months.	Jail.	Under 3 months.	Over 3 months.
	oz.	oz.		oz.	oz.
Allahabad ...	0·59	0·67	Meerut	0·65	0·73
Bareilly	0·66	0·74	Moradabad ...	0·53	0·61
Benares	0·63	0·70	Rai Bareilly ...	0·65	0·73

TABLE VIII.

Average Daily Nutritive Value of the Diets actually issued to Labouring Prisoners during 1880 *in six* CENTRAL *Jails in the* NORTH-WESTERN PROVINCES *and* OUDH.

INGREDIENTS ENTERING INTO THE SEVERAL DIETS.	AGRA.							ALLAHABAD.							BAREILLY.							Serial Number.
	Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						
		3 months and under.			Over 3 months.				3 months and under.			Over 3 months.				3 months and under.			Over 3 months.			
		Quantity in Ounces.	Nutritive value in grains.		Quantity in Ounces.	Nutritive value in grains.			Quantity in Ounces.	Nutritive value in grains.		Quantity in Ounces.	Nutritive value in grains.			Quantity in Ounces.	Nutritive value in grains.		Quantity in Ounces.	Nutritive value in grains.		
			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.	
II.																						I
1. Cereal flour—																						1.
a.—*Wheat* ...	2,650·4	7·2	66·3	1,224·0	7·2	66·3	1,224·0	4,172·4	11·4	105·1	1,938·0	11·4	105·1	1,938·0	4,957·9	13·5	124·4	2,295·0	13·5	124·4	2,295·0	a.
b.—*Bajra* ...	706·8	1·9	13·3	323·0	1·9	13·3	323·0	490·2	1·4	9·8	238·0	1·4	9·8	238·0	858·8	2·4	16·8	408·0	2·4	16·8	408·0	b.
c.—*Maize* ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	75·4	0·2	1·3	34·0	0·2	1·3	34·0	c.
d.—*Jowar* ...	1,732·8	4·7	28·0	799·0	4·7	28·0	779·0	114·0	0·3	1·7	51·0	0·3	1·7	51·0	902·5	2·5	14·9	425·0	2·5	14·9	425·0	d.
e.—*Barley* ...	2,456·4	6·7	38·9	1,139·0	6·7	38·9	1,139·0	22·8	0·06	0·3	10·2	0·06	0·3	10·2	887·1	2·4	13·9	408·0	2·4	13·9	408·0	e.
f.—*Gram** ...	1,014·4	2·8	50·0	476·0	2·8	50·0	476·0	3,545·4	9·7	173·2	1,649·0	9·7	173·2	1,649·0	663·1	1·8	32·1	306·0	1·8	32·1	306·0	f.
g.—*Urd** ...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	g.
2. Pulse	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	2.
3 to 6 as in I ...	...	...	3·5	198·4	...	3·5	198·4	...	...	3·5	198·4	...	3·5	198·4	...	...	3·5	198·4	...	3·5	198·4	3.
Average daily nutritive value =		220	4,346		...	311	5,213	*Average daily nutritive value*	313	4,272		...	404	5,139	*Average daily nutritive value*	226	4,261		...	318	5,128	...

Ingredients entering into the several Diets.	Benares.							Lucknow.							Meerut.							Serial Number.
	Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						Ounces of cereal, &c., flour per head issued during 1880.	Average daily Diets of Labouring Prisoners.						
		3 months and under.			Over 3 months.				3 months and under.			Over 3 months.				3 months and under.			Over 3 months.			
		Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.			Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.			Quantity in ounces.	Nutritive value in grains.		Quantity in ounces.	Nutritive value in grains.		
			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.			Nitrogen.	Carbon.		Nitrogen.	Carbon.	
II																						I
1. Cereal flour—																						1.
a.—*Wheat* ...	2,329·9	6·4	59·0	1,088·0	6·4	59·0	1,088·0	4,033·8	11·0	101·4	1,870·1	11·0	101·4	1,870·0	6,675·9	18·2	167·8	3,091·0	18·2	167·8	3,094·0	a.
b.—*Bajra* ...	823·3	2·2	15·4	374·0	2·2	15·4	374·0	385·4	1·1	7·7	187·0	1·1	7·7	187·0	...	...	...	...	...	...	...	b.
c.—*Maize* ...	157·3	0·4	2·7	68·0	0·4	2·7	68·0	...	...	...	...	...	...	...	...	...	...	...	...	...	...	c.
d.—*Jowar* ...	1,122·9	3·1	18·5	527·0	3·1	18·5	527·0	2,209·9	6·0	35·8	1,020·0	6·0	35·8	1,020·0	...	...	...	...	...	...	...	d.
e.—*Barley* ...	4,229·5	11·5	66·8	1,955·0	11·5	66·8	1,955·0	958·8	2·6	15·1	442·0	2·6	15·1	442·0	...	...	...	...	...	...	...	e.
f.—*Gram** ...	31·3	0·1	1·7	17·0	0·1	1·7	17·0	1,406·3	3·8	67·8	646·0	3·8	67·8	646·0	1,668·9	4·6	82·1	782·0	4·6	82·1	782·0	f.
g.—*Urd** ...	...	...	...	...	...	...	...	500·2	1·4	25·0	238·0	1·4	25·0	238·0	...	...	...	...	...	...	...	g.
2. Pulse	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	...	1·1	19·6	187·0	6·2	110·7	1,054·0	2.
3 to 6 as in I ...	...	...	3·5	198·4	...	3·5	198·4	...	...	3·5	198·4	...	3·5	198·4	...	...	3·5	198·4	...	3·5	198·4	3.
Average daily nutritive value =			**187**	**4,414**	...	**278**	**5,281**	*Average daily nutritive value*		**276**	**4,788**	...	**367**	**5,655**	*Average daily nutritive value*		**273**	**4,261**	...	**364**	**5,128**	...

* To avoid confusion *Gram* and *Urd* have been tabulated amongst the cereals, as they have been issued instead of staple cereal. The calculation, however, has been carried t as for other pulses except as regards the fatty matter in Gram, which has been taken as 3·7 per cent.

The amount of Fatty Substances in each of the above Diet Scales:—

Jail.	Under 3 months.	Over 3 months.	Jail.	Under 3 months.	Over 3 months.
	oz.	oz.		oz.	oz.
Agra	0·74	0·82	Benares	0·69	0·77
Allahabad ...	0·76	0·84	Lucknow	0·81	0·89
Bareilly	0·70	0·78	Meerut	0·63	0·71

TABLE IX.

The Weekly scales of Diet for Labouring Prisoners in the PUNJAB JAILS *with their average daily Nutritive values.*

INGREDIENTS ENTERING INTO THE SEVERAL DIETS.	I.—ORDINARY DIETS.												II.—SPECIAL DIETS.						Serial number.
	(*a*) 20 oz. Wheat, twice weekly. 24 oz. Barley, twice weekly. 24 oz. Mukka, thrice weekly.			(*b*) 20 oz. Wheat, twice weekly. 24 oz. Barley, twice weekly. 24 oz. Bajra, thrice weekly.			(*c*) 20 oz. Wheat, twice weekly. 24 oz. Jowar, twice weekly. 24 oz. Mukka, thrice weekly.			(*d*) 20 oz. Wheat, twice weekly. 24 oz. Jowar, twice weekly. 24 oz. Bajra, thrice weekly.			(*a*) Rawal Pindi Jail.			(*b*) Rupar Jail.			
	Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. Cereal flour—																			1
a.—Wheat	40	368·8	6,800	40	368·8	6·800	40	368·8	6,800	40	368·8	6·800	140	1,290·8	23,800	160	1,475·2	27,200	*a*
b.—Barley	48	278·8	8,160	48	278·8	8,160	...	...	...	...	...	...	...	...	...	...	...	...	*b*
c.—Mukka	72	498·9	12,240	...	...	...	72	498·9	12,240	...	...	...	...	...	...	...	...	...	*c*
d.—Bajra	...	...	...	72	504·0	12,240	...	...	...	72	504·0	12,240	...	...	...	...	...	...	*d*
e.—Jowar	...	...	...	...	...	...	48	286·5	8,160	48	286·5	8,160	...	...	...	...	...	...	*e*
2. Gram	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	78	1,393·0	13,260	2
3. Meat	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	8	82·8	512	3
4. Pulse (urd or mung)	25	446·5	4,250	25	446·5	4,250	25	446·5	4,250	25	446·5	4,250	33	589·3	5,610	30	535·8	5,100	4
5. Vegetables	24	16·8	804·0	24	16·8	804	24	16·8	804	24	16·8	804	24	16·8	804	24	16·8	804	5
6. Oil or ghee	1·75	...	604·8	1·75	...	604·8	1·75	...	60·-8	1·75	...	604·8	1·5	...	518	1·5	...	518	6
7. Salt	1·75	...	...	1·75	...	...	1·75	...	...	1·75	...	...	3·5	...	...	3·5	...	...	7
8. Condiments	1·75	...	...	1·75	...	...	1·75	...	...	1·75	...	...	3·5	...	...	2·6	...	...	8
Average daily Nutritive value ... =		301	5,374	...	302	5,374	...	302	5,374	...	303	5 374	...	342	5,070	...	500	6,771	

Modifications of "Ordinary" Diets during May, June, July, August and September.

	(a) 20 oz. Wheat, twice weekly. 24 oz. Barley, twice weekly. 18 oz. Barley, thrice weekly. 6 oz. Gram, thrice weekly.			(b) 20 oz. Wheat, twice weekly. 16 oz. Barley, twice weekly. 6 oz. Gram, twice weekly. 24 oz. Mukka, thrice weekly.			(c) 20 oz. Wheat, twice weekly. 10 oz. Wheat, twice weekly. 10 oz. Barley, twice weekly. 18 oz. Barley, thrice weekly. 6 oz. Gram, thrice weekly.			(d) 20 oz. Wheat, twice weekly. 10 oz. Wheat, twice weekly. 10 oz. Gram, thrice weekly. 24 oz. Mukka, thrice weekly.			(e) 20 oz. Wheat, twice weekly. 24 oz. Barley, twice weekly. 10 oz. Wheat, thrice weekly. 10 oz. Gram, thrice weekly.			(f) 20 oz. Wheat, twice weekly. 18 oz. Barley, twice weekly. 6 oz. Gram, twice weekly. 10 oz. Wheat, thrice weekly. 10 oz. Gram, thrice weekly.			
	Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Serial number.
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. Cereal flour—																			1
a.—Wheat	40	368·8	6,800	40	668·8	6,800	60	553·2	10,200	60	553·2	10,200	70	645·4	11,900	70	645·4	11,900	*a*
b.—Barley	102	592·6	17,340	36	209·1	6,120	74	429·9	12,580	...	...	...	48	278·8	8·160	36	209·1	6,120	*b*
c.—Mukka	...	...	...	72	498·9	12,240	...	...	...	72	498·9	12,240	...	...	...	...	...	...	*c*
2. Gram	46	821·5	7,820	40	714·4	6,800	46	821·5	7,820	48	857·2	8,160	58	1,035·8	9,860	70	1,250·2	11,900	2
3. Pulse (urd or mung)	25			25			25			25			25	446·5	4,250	25			3
4. Vegetables	24			24			24			24			24	16·8	804	24			4
5. Oil or ghee	1·75	463·3	5,659	1·75	463·3	5,659	1·75	463·3	5,659	1·75	463·3	5,659	1·75	...	604·8	1·75	63·3	5,659	5
6. Salt	1·75			1·75			1·75			1·75			1·75	...	...	1·75			6
7. Condiments	1·75			1·75			1·75			1·75			1·75	...	...	1·75			7
Average daily Nutritive value ... =		321	5,374	...	322	5,374	...	324	5,180	...	339	5,180	...	346	5,083	...	367	5,083	

TABLE X.

The Former and the Present, or Reduced, Weekly scales of Diet for Labouring Prisoners in the CENTRAL PROVINCES *and their daily average Nutritive values.*

* INGREDIENTS ENTERING INTO THE DIETS.	I.—FORMER OR STANDARD SCALE. 20·5 oz. Wheat,* twice weekly. 24·6 „ Bajra,* „ „ 24·6 „ Jowar,* thrice „						II.—PRESENT OR REDUCED SCALE. 16·4 oz. Wheat,* twice weekly. 20·5 „ Bajra,* „ „ 20·5 „ Jowar,* thrice „						Serial number.
	(*a*) LESS THAN 6 MONTHS.			(*b*) OVER 6 MONTHS.			(*a*) LESS THAN 6 MONTHS.			(*b*) OVER 6 MONTHS.			
	Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		
		Nitrogen.	Carbon.		Nitrogen	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. *Cereal flour**—													1.
a.—Wheat	41·0	378·0	6,970·0	41·0	378·0	6,970·0	32·8	302·4	5,576·0	32·8	302·4	5,576·0	*a.*
b.—Bajra	49·2	344·4	8,364·0	49·2	344·4	8,364·0	41·0	287·0	6,970·0	41·0	287·0	6,970·0	*b.*
c.—Jowar	73·8	440·5	12,546·0	73·8	440·5	12,546·0	61·5	367·1	10,455·0	61·5	367·1	10,455·0	*c.*
2. Gram	28·7	512·5	4,879·0	28·7	512·5	4,879·0	28·7	512·5	4,879·0	28·7	512·5	4,879·0	2.
3. Pulse	24·6	439·3	4,182·0	28·7	512·5	4,879·0	24·6	439·3	4,182·0	28·7	512·5	4,879,0	3.
4. Vegetables	24·6	17·2	824·1	24·6	17·2	824·1	24·6	17·2	824·1	24·6	17·2	824·1	4.
5. Fatty matter	1·8	...	622·0	3·07	...	1,060·9	1·8	...	622·0	3·07	...	1,060·9	5.
6. Salt	2·8	...	...	2·8	...	...	2·8	...	...	2·8	...	...	6.
7. Chillies	0·64	...	...	0·64	...	...	0·64	...	...	0·64	...	...	7.
Daily average Nutritive value ... ... =		**304**	**5,484**	...	**315**	**5,646**	...	**275**	**4,787**	...	**285**	**4,949**	

* Rice may be substituted for any of these cereals at the discretion of the medical officer.

Former and Present scales of Diet for Labouring Prisoners in the Jails of the Hyderabad Assigned Districts.

Ingredients entering into each Diet.	Diets in force till towards the end of 1879.						Diets in force from towards the end of 1879 till March 1881.						Present maximum diet scale.			
	Under 3 Months.			Over 3 Months.			Under 3 Months.			Over 3 Months.						
	22 oz. Jowar, thrice weekly. 21 oz. Wheat, thrice weekly. 16·5 oz. Wheat, thrice weekly.			22 oz. Jowar, thrice weekly. 21 oz. Wheat, thrice weekly. 16·5 oz. Wheat, thrice weekly.			20 oz. Jowar, four times weekly. 18 oz. Wheat, three times weekly.			24 oz. Jowar, four times weekly. 22 oz. Wheat, three times weekly.			24 oz. Jowar, four times weekly. 22 oz. Wheat, three times weekly.		
	Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.	
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.
1. *Cereals*—															
a.—Wheat	79·5	732·9	13,515	79·5	732·9	13,515	54	497·8	9,180	66	608·5	11,220	66	608·5	11,220
b.—Jowar	66	394·0	11,220	66	394·0	11,220	80	477·6	13,600	96	573·1	16,320	96	573·1	16,320
2. Pulse	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	42	750·1	7,140
3. Gram	45·5	812·6	7,735	45·5	812·6	7,735	...	...	...	...	...	...	...	...	...
4. Vegetables	24	16·8	804	56	39·2	1,876	28	19·6	938	42	29·4	1,407	42	29·4	1,407
5. Fatty matter	3	...	1,036·8	3	...	1,036·8	1·75	...	604·8	1·75	...	604·8	3·5	...	1,209·6
6. Tamarind	1·5	13·1	26·2	1·5	13·1	26·2	...	...	...	...	...	...	...	...	...
7. Salt	2·2	...	...	3·2	...	...	3·5	...	...	3·5	...	...	3·5	...	...
8. Condiments	2·3	...	...	2·3	...	...	1·75	...	...	2·6	...	...	3·5	...	...
Daily average Nutritive value =		**353**	**5,585**	...	**356**	**5,738**	...	**213**	**4,155**	...	**244**	**4,902**	...	**280**	**5,328**

TABLE XII.

The scales of Diet in force for Labouring Prisoners in MYSORE *and* COORG.

Serial number.	INGREDIENTS ENTERING INTO THE SEVERAL DIETS.	(*a*) 6 MONTHS AND UNDER.			(*b*) OVER 6 MONTHS AND UP TO TWO YEARS.			(*c*) OVER TWO YEARS.			Serial number.
		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRAINS.		Ounces weekly.	NUTRITIVE VALUE IN GRIANS.		
			Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1	Rice	24	121·6	4,030	36	182·5	6,120	36	182·5	6,120	1
2	Ragi	144	921·6	24,480	132	844·8	22,440	143	915·2	24,310	2
3	Meat* (with bone)	4	33·1	205	9	74·5	461	12	99·3	614	3
4	Pulse	19	339·3	3,230	22	392·9	3,740	22	392·9	3,740	4
5	Vegetables	42	29·4	1,407	42	29·4	1,407	42	29·4	1,407	5
6	Tyre (buttermilk)	...	...	...	24	67·2	600	24	67·2	600	6
7	Fatty matter	·875	...	302·4	2·25	...	777·6	2·25	...	777·6	7
8	Salt	4·375	...	...	5·25	...	...	5·25	...	...	8
9	Condiments	5·9	...	...	6·6	...	...	6·6	...	...	9
10	Tamarind	3·5	30·6	61·2	3·5	30·6	61·2	3·5	30·6	61·2	10
Average daily nutritive value ... ... =			**211**	**4,824**	...	**232**	**5,088**	...	**245**	**5,376**	...

* One-fifth has been deducted on account of bone.

TABLE XIII.

The Daily scale of Diets allowed to Labouring Prisoners in the Jails of British Burma, and their average nutritive values.

Ingredients entering into the several Diets.	MEAT FORM OF DIET.						FISH FORM OF DIET.						Serial number.
	(a) Under three Months.			(b) Above three Months.			(c) Under three Months.			(d) Above three months.			
	Ounces.	Nutritive value in grains.		Ounces.	Nutritive value in grains.		Ounces.	Nutritive value in grains.		Ounces.	Nutritive value in grains.		
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. Rice	20	101·4	3,400	24	121·6	4,080	20	101·4	3,400	24	121·6	4,080	1
2. Meat	2	20·7	128	4	41·4	256	...	...	...	...	...	...	2
3. Fish	...	...	...	...	...	...	2	23	104·8	4	46	209·6	3
4. Vegetables	6	4·2	201	8	5·6	268	6	4·2	201	8	5·6	268	4
5. Fatty matter	·5	...	172·8	·5	...	172·8	·5	...	172·8	·5	...	172·8	5
6. Gnapee*	...	...	...	·5	5·7	26·2	...	...	...	·5	5·7	26·2	6
7. Salt	·5	...	...	·5	...	...	·5	...	...	·5	...	...	7
8. Condiments	·5	...	...	·5	...	...	·5	...	...	·5	...	...	8
Average daily Nutritive value ... =		126	3,902	...	174	4,803	...	129	3,879	...	179	4,757	

* This has been treated as fish, but as decomposition reduces the amount of nitrogen which fish contains the estimate is probably too high. It should perhaps be looked upon more as a condiment than as an aliment.

TABLE XIV.

The Weekly scale of Diets for Third class and Chain-gang convicts at the ANDAMAN ISLANDS.

INGREDIENTS ENTERING INTO EACH DIET.	I.—ORDINARY DIETS.‡						II.—DIETS WHEN FISH IS NOT PROCURABLE.‡						Serial number.
	Staple Cereal.						*Staple Cereal.*						
	(*a*) Rice.			(*b*) Wheat.			(*a*) Rice.			(*b*) Wheat.			
	Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. Rice	182*	922·7	30,940	14	70·9	2,380	217*	1,100·1	30,890	49*	248·4	8,330	1
2. Wheat-flour	...	...	...	140	1,290·8	23,800	...	...	...	140	1,290·8	23,800	2
3. Pulse	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	28	500·0	4,760	3
4. Fish	20	230	1,048	20	230	1,048	...	...	...	...	...	...	4
5. Dhai†	12	33·6	300	12	33·6	300	12	33·6	300	12	33·6	300	5
6. Vegetables...	56	39·2	1,876	56	39·2	1,876	56	39·2	1,876	56	39·2	1,876	6
7. Fatty matter	7	...	2,419·2	7	...	2,419·2	7	...	2,419·2	7	...	2,419·2	7
8. Tamarinds...	3·5	30·6	61·2	3·5	30·6	61·2	3·5	30·6	61·2	3·5	30·6	61·2	8
9. Salt	3·5	...	...	3·5	...	...	3·5	...	...	3·5	...	...	9
10. Condiments	3·5	...	...	3·5	...	...	3·5	...	...	3·5	...	...	10
Average daily Nutritive value	=	**251**	**5,915**	...	**314**	**5,235**	...	**243**	**6,615**	...	**306**	**5,935**	

* This includes 2 oz. of rice made into *congee*.

† Curdled skimmed milk.

‡ Convicts working in particularly unhealthy districts are allowed from 10 to 16 ounces of milk in addition.

TABLE XV.

The Daily Diet scales of Labouring Prisoners in the BOMBAY PRESIDENCY, *with their Nutritive values.*

INGREDIENTS ENTERING INTO THE SEVERAL DIETS.	A.—BOMBAY CITY JAIL.			B.—OTHER JAILS IN THE PRESIDENCY.																
				I.—PRISONERS ON INTRAMURAL OR MEDIUM LABOUR.									II.—PRISONERS ON *bonâ fide* HARD LABOUR.								
	WHEAT-FLOUR.			(*a*) WHEAT-FLOUR.			(*b*) BAJRA-FLOUR.			(*c*) JOWARI-FLOUR.			(*a*) WHEAT-FLOUR.			(*b*) BAJRA-FLOUR.			(*c*) JOWARI-FLOUR.			
	Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		Ounces daily.	Nutritive value in grains.		Serial number.
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
1. Cereal flour ...	8	73·7	1,360	20	184·4	3,400	20	140	3,400	20	119·4	3,400	24·0	221·2	4,080	24·0	168	4,080	24·0	143·2	4,080	1
2. Rice	8	40·5	1,360	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	2
3. Pulse	5	89·3	850	4	71·4	680	4	71·4	680	4	71·4	680	5·0	89·3	850	5·0	89·3	850	5·0	89·3	850	3
4. Vegetables... ...	8	5·6	268	6	4·2	201	6	4·2	201	6	4·2	201	8·0	5·6	268	8·0	5·6	268	8·0	5·6	268	4
5. Fatty matter ...	·5	...	172·8	·25	...	86·4	·25	...	86·4	·25	...	86·4	1·0	...	345·6	1·0	...	345·6	1·0	...	345·6	5
6. Salt	0·4	...	...	0·4	...	...	0·4	...	...	0·4	...	...	0·4	...	...	0·4	...	...	0·4	...	...	6
7. Condiments ...	1	...	...	·25	...	...	0·25	...	...	0·25	...	...	1	...	...	1	...	...	1	...	...	7
Average daily Nutritive value		209	4,011	...	260	4,367	...	216	4,367	...	195	4,367	...	316	5,544	...	263	5,544	...	238	5,544	
Average daily Nutritive value of 5 oz. Meat to be given instead of 5 oz. Pulse* =				...	230	3,943	...	186	3,943	...	165	3,943	...	278	5,014	...	225	5,014	...	200	5,014	

* Meat may be given in the Bombay City Jail also, if ordered by the Medical Officer: the amount is not stated.

TABLE XVI.

The Weekly scales of Diet for Labouring Prisoners in the MADRAS PRESIDENCY, *and the average Daily Nutritive values.*

INGREDIENTS ENTERING INTO THE SEVERAL DIETS.	(*a*) RAGI.			(*b*) CHOLUM (JOWAR).			(*c*) CUMBOO (BAJRA).*			Serial number.
	Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		Ounces weekly.	Nutritive value in grains.		
		Nitrogen.	Carbon.		Nitrogen.	Carbon.		Nitrogen.	Carbon.	
A.—CENTRAL JAIL.										
1. Cereal	146	934·4	24,820	146	871·6	24,820	152	1,064·0	25,840	1
2. Rice	24	121·6	4,080	24	121·6	4,080	24	121·6	4,080	2
3. Pulse	14	250·0	2,380	14	250·0	2,380	14	250·0	2,380	3
4. Meat†	15	155·2	960	15	155·2	960	15	155·2	960	4
5. Vegetables	28	19·6	938	28	19·6	938	28	19·6	938	5
6. Tyre‡	40	112·0	1,000	40	112·0	1,000	40	112·0	1,000	6
7. Fatty matter	3·5	...	1,209·6	3·5	...	1,209·6	3·5	...	1,209·6	7
8. Tamarind	3·5	30·6	61·2	3·5	30·6	61·2	3·5	30·6	61·2	8
9. Salt	7	...	...	7	...	...	7	...	...	9
10. Condiments§	7·2	...	...	7·2	...	...	7·2	...	...	10
Average daily Nutritive value =		**232**	**5,064**	...	**223**	**5,064**	...	**250**	**5,210**	...
B.—DISTRICT AND SUBSIDIARY JAILS. **I.—CONVICTS OF FROM ONE TO FOUR MONTHS.**										
1. Cereal	140	896	23,800	140	835·8	23,800	146	1·022·0	24,820	1
2. Rice	...	...	...	...	...	...	...	...	...	2
3. Pulse	21	375·0	3,570	21	375·0	3,570	21	375·0	3,570	3
4. Meat†	...	...	...	...	...	...	...	...	...	4
5. Vegetables	28	19·6	938	28	19·6	938	28	19·6	938	5
6. Tyre‡	30	84	750	30	84	751	30	84·0	750	6
7. Fatty matter	3·5	...	1,209·6	3·5	...	1,209·6	3·5	...	1,209·6	7
8. Tamarind	3·5	30·5	61·2	3·5	30·6	61·2	3·5	30·6	61·2	8
9. Salt	5·25	...	...	5·25	...	...	5·25	...	...	9
10. Condiments§	7	...	...	7	...	...	7	...	...	10
Average daily Nutritive value =		**201**	**4,333**	...	**192**	**4,333**	...	**219**	**4,478**	...
II.—CONVICTS OF MORE THAN FOUR MONTHS.										
1. Cereal	168	1,075·2	28,560	168	1,002·9	28,560	175	1,225·0	29,750	1
2. Rice	...	...	...	...	...	...	...	...	...	2
3. Pulse	14	250·0	2,380	14	250·0	2,380	14	250·0	2,380	3
4. Meat†	15	155·2	960	15	155·2	960	15	155·2	960	4
5. Vegetables	28	19·6	938	28	19·6	938	28	19·6	938	5
6. Tyre‡	30	84·0	750	30	84	750	30	84	750	6
7. Fatty matter	3·5	...	1,209·6	3·5	...	1,209·6	3·5	...	1,209·6	7
8. Tamarind	3·5	30·6	61·2	3·5	30·6	61·2	3·5	30·6	61·2	8
9. Salt	5·25	...	...	5·25	...	...	5·25	...	...	9
10. Condiments§	7·2	...	...	7·2	...	...	7·2	...	...	10
Average daily Nutritive value =		**231**	**4,980**	...	**220**	**4,980**	...	**252**	**5,150**	...

* 25 Ounces of cumboo to be considered "as equivalent to 24 ounces of ragi or cholum."
† Or fish. ‡ Skimmed (?) milk.
§ Includes ½ oz. curry powder, ½ oz. onions, and 30 grains of garlic daily.

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