A thesis
"On some of the more important facts relating to the cause and prevention of Indian Cholera"

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Bacteriology

The bacteriology of cholera belongs to a very recent date. Before that period, cholera used to be spoken of as due to telluric influences, pandemic waves, epidemic constitution and the so-called “blue mist”. Even Providence itself was supposed to be causally connected with the disease. Inverted, the infectious nature of cholera stools, has been recognised long since, and numerous were the attempts made to investigate the true nature of the disease. But all these proved futile, and led to no practical result. It was not till 1883, that Koch by his brilliant researches in Egypt, & elsewhere, discovered a peculiar organism, which is now generally admitted, as the causa causans of cholera. The organisms were constantly present in the defeces of patients, but were rarely so in the vomit, & never in the blood. On examining cholera corpses, he failed to find anything abnormal in other viscera, although important pathological changes were noticed in intestines. This was precisely as he had anticipated, for cholera was after all an intestinal disease.
He found moreover, that the intestinal changes varied, according to the intensity 
and duration of the process. Thus, in acute uncomplicated cases, the mucus membrane of 
small intestine was slightly swollen and hyperaemic. Its contents were colourless like 
gruel or rice water, and contained comma bacilli in almost pure cultures. In cases 
which were more protracted, the alterations of 
the mucus membrane were more marked, 
and showed patchy redness, especially at 
the margins of the follicles and of Peyer's 
patches. Comma bacilli were lying in large 
numbers in the tube-like glands,—a few 
however had penetrated between the epithel 
and basement membrane, detaching the former 
from its base. Various other bacteria were 
seen in the tubular glands, and surrounding 
tissues. But the curved bacilli always feed 
the latter,—they penetrated deeper into the tissue 
and appeared as if they had opened the way 
for other bacilli. In typhoid cases, owing 
to the longer duration of disease, secondary 
alterations had occurred, & obscured the typical 
conditions we have just mentioned. The
mucus membrane showed superficial haemorrhages, at times appeared to have undergone superficial necrosis. The intestinal contents, consisted of a bloody stinking fluid, and in it the commas were often difficult to recognise, owing to the preponderance of other kinds of bacteria.

Comma bacilli were constantly found in all cases,—indeed, they have seldom been missed in true cholera. They are met with in cholera, and in cholera alone. Where the disease causes most marked changes in intestine (i.e. in the lower half of small intestine) they are found most numerously, alone this they diminish more and more. This constant occurrence of comma bacilli and their limitation to cholera, cannot be regarded as accidental coincidence. On the contrary, the cholera process and comma bacilli must be related to each other as cause and effect. Therefore, either cholera process is the cause of the presence of a large number of comma bacilli, or the latter, the cause of cholera. On the first assumption, there can be
only two explanations of the appearance of
commas. Either these organisms, multiply
largely, as the result of cholera process, from
a few commas constantly present in the
normal intestine: against this however, we
have the constant negative results of numerous
investigations of normal intestinal contents.
Besides, we do not know of any disease
in which such a thing ever occurs.

The second hypothesis of the
occurrence of comma bacilli is still more
unlikely, i.e. that these organisms have been
developed, as a result of the influence of
cholera disease, from other species of vibrios
which are normally present in the intestine.
But such a transformation of one species
into another, which occurs in such a regular
recurring and exclusive manner under the
influence of a definite disease, has never
been observed—nay, such a possibility
is absolutely inconsistent with the fundamental
principles of Bacteriology.

Therefore, the only conclusion
which the logic of facts forces us to accept
is, that comma bacilli are the cause of cholera.
Such an inference, is in absolute accord with what we know of the causation of other infectious diseases. It is only conclusion, which helps us to give a rational interpretation, of the divers phenomena of the disease. It has stood, the test of time, & the criticism of opponents, so that our faith in the causal relationship of comma bacillus, is as strong as ever.

The comma bacillus, or rather Cholera spirillum, occurs as a curved rod, from one half to one third the length of Tubercle bacillus, but somewhat thicker. It may occur singly, or in pairs, in which the curve may be continued or reversed, so giving rise to the formation of half circles or of S-shaped curves. Its stab cultures in gelatine are characteristic; there is a whitish growth along the needle track with gradual liquefaction, which at first is more marked near the surface, so that a funnel-shaped depression is formed, which contains an air bubble. Liquefaction is comparatively slow; but after six days it has progressed so far, as to destroy the appearance just described.
On agar agar we have a superficial slimy growth offering no special features. In meat infusion or peptone solution it forms a greyish felicile on the surface. Gelatine plates are very characteristic, and are considered by some observers to have a distinct diagnostic value. The superficial colonies at earliest stages present an irregular shape and have a coarsely granular appearance (while colonies of all other vibrios, except Denelke's, are round and structureless). The deeply seated colonies present at an early age, an irregular shape and a wavy uneven surface. Gradually, as the liquefaction of the nutrient medium proceeds, this appearance is lost.

While gelatine, agar &c on which the organisms are expected to thrive must be of marked alkaline reaction, the cholera vibrios possess a notable capacity of accommodating themselves to acid media, provided the acid is of vegetable origin. The surface of boiled potato has often a feeble acid reaction (due to fumaric acid) yet the organisms develop on it, only of course by the aid of increased temperature.
If mucus flakes from the ileum of an acute case, are placed on linen kept damp in a closed glass chamber between 20° and 37°C, a very exact cultivation of the cholera organism can be obtained on blood serum, the organisms grow most luxuriantly, and may cause slight liquefaction. They also thrive and multiply, in sterilised milk, without perceptibly changing the fluid. In non-sterilised milk they live for only a short period, with the appearance of acidification, the organisms are destroyed, but so much time usually elapses that the fluid in most cases would be consumed before this occurs.

Cholera bacteria, usually possess a single terminal flagellum. They exhibit a lively motion, swimming and whirling through the microscopic field, "like a swarm of dancing gnats." The vibrios are stained by various aniline dyes, but a saturated watery solution of fuchsin is the most efficient. They are decolorised by Gram.
Shores (?)

Hueppe claims to have seen in moist chamber cholera cultivations on agar agar small brilliant shore like bodies, which he called "arthroshores". Such an idea would only be justified, when it was clearly shown that this body was distinctly more resistant, and hence of service for the maintenance of species, and that it could resist drying and concurrence with saprophytes. But it has been demonstrated again and again, that these organisms are very easily killed by drying, and other bacteria. Again shores have not been found by any other observer, & Hueppe himself has only seen them thrice. Speaking a priori, we may note, that cholera virions stand in no need for shores, for they are always associated with fluids, and do not, like Bacillusanthracis grow under conditions, in which they have to exist at times in a dry state. Besides, the want of resting stage is in complete accord with our experience of the etiology of the disease. It would therefore be best to regard the "arthroshores" of Hueppe, merely as involution forms resulting from the degenerative changes occurring in the organism.
Vitality of Cholera Vibrio.

Although a true resting stage is absent, yet these organisms are more resistant than is generally supposed. In fact, they are so little fastidious in their diet, that they will grow on almost anything. They thrive best from 35° to 37°C if the medium is faintly alkaline, but nevertheless, they possess a remarkable capacity of accommodating themselves to the varying conditions of their media.

In fecal matter cholera vibrios as a rule die out within the first 20 days and often cannot be obtained after 20 or 3 days. In water, they remain alive for many days in sterile distilled water for 73 days to an year; in sterile well water for months, but in unsterile water for from 4 to 25 days. Orgel succeeded in keeping them alive for almost a year. They are rapidly killed in soda water, in consequence of the germicidal action of the gas. In India, where owing to high temperature they are bottled at a higher pressure than in England, infection by means of aerated waters must be an unlikely occurrence. Distilled water is never
sufficient for their nutrition, and if the strength of any of the usual cultivation media be reduced to about a fortieth of the original strength there is a gradual diminution in the number of organisms. Wernicke introduced a large quantity of cholera comas into an experimental aquarium, in which there were weeds & other water bacteria. This was regularly exposed to diffused and direct sunlight. Three months after this, the vibrios could be detected in water, on weeds and in mud at the bottom of the vessel.

"Comma bacilli survive upon slices of rye bread freely exposed to the air for 24 hours, but when the bread was wrapped in paper for three days. They thrive exceedingly well on carbohydrates & we have strong reasons for believing that infection by means of rice, plays an important role in the etiology of Indian cholera. Upon slightly acid butter they survive for from 4 to 6 days; on roasted meat (protected from drying) for about a week. The bacilli die very quickly in wines.

When kept moist upon the surface
of fruits they retain their vitality for from 1 to 7 days. They live longest on melons and cucumbers. On the whole, acidity of fruits favours the death of the organisms. They do not exist longer than 24 hours on mustard, onions and on the confectionary of sugar.

They may survive upon the printed pages of a book for 17 hours; and upon writing paper enclosed in an envelope for about 24 hours; upon coins for half an hour and upon the dry hand for an hour.

Conditions of death of Comma

(1) Drying.

If a cultivation is spread out on a coverglass and exposed to the action of air at ordinary temperature, the organisms are found to be dead after 2 or 3 hours, so that no development occurs when the coverglass is placed in nutrient jelly.

(2) High temperature.

Exposure for half an hour to 60°C destroys the vitality of the organisms.
(3) Alcohol, Sulphate of Iron, Quinine, Carabolic acid &c., are all highly efficient germicides. They are readily killed by Hydrochloric acid, but can withstand the action of vegetable acids.

(4) Cholera bacilli being somewhat exclusive in their habits, are quickly overpowered by the vulgar saprophytic bacteria. Thus if added to sewage they cannot be found after 24 hours. If, however, they are in large numbers & the conditions of life are favourable they gain the upper hand in the first instance, but gradually die out after a couple of days' existence.

(5) Sunshine, including free air, is certainly the best ‘natural’ disinfectant we have. Subjoined are the results obtained by Palermo of the action of sunshine on the virulence of comma bacilli. Broth cultures were used in the experiments, but the results were more satisfactory when sterilised distilled water was used instead.
Exposure to Sunshine  Effect on Guinea Pig

0  ---  Animal died in 18 hours.
10 mins. to 2 hrs.  ---  "  "  "
3 hours  ---  One animal died in 18 hours, but another also inoculated with the same liquid died after 5 day.
3½ to 4½ hrs.  ---  Remained alive.

These experiments, though not absolutely free from doubt, are amply borne out by our practical experience. The comparative freedom of Indian rivers from organismal life, is very largely due to the benign influence of Insolation. But the lethal action of sunshine, can only be exerted on the surface of the column of water. In the deeper layers however, it supplies the necessary temperature, and thus induces the multiplication of the organisms. It therefore appears to us, that the influence of sunshine on comma bacilli is twofold; — a destructive action at the surface, and growth in the depths of the medium.
Experiments on Animals.

Long before the discovery of comma bacilli, numerous attempts were made to produce cholera in animals, but all these ended in uniform failure, owing to the fact that the lower animals are immune to this disease. In Bengal, the fatherland of cholera, where domestic animals live in close association with people, and have free access to the various foci of infection, they remain remarkably free from cholera. For have any cases been observed, in places where disease occurs as an epidemic.

Thiersch fed white mice with scraps of filter paper soiled with cholera defaecata but he found that plain filter paper was equally efficacious in causing the illness of the white mice. Lewis and Cunningham by a series of experiments on dogs in which they injected into the veins of these animals, the defaecata of cholera patients of persons in good health, observed that the symptoms and pathological changes induced by both are alike but that the proportion of cases, in which a definite effect on
intestinal mucus membrane was produced, was far greater when cholera fluid was employed than otherwise.

Next Koch tried to produce cholera by feeding and inoculating in various ways monkeys, cats, dogs, poultry to limit without any success. On searching, the bacilli however were invariably absent, apparently having been destroyed in the stomach, as in only a few instances did they reach the intestine at all, and then in very small numbers.

To demonstrate the difference between these and certain other bacteria, a mouse was fed with a red microorganism and after a 'time its' intestinal contents were grown on potato, on which the characteristic red colonies appeared, proving that they had escaped unharmed from the gastric juice.

In guineahogs, in which he attempted to produce cholera, he found that there was great acidity of the gastric juice, and that the peristaltic movements of the intestines, were very strong and rapid.

Pichat & Rietsch, utilising this knowledge, and struck by the fact
that in cholera cases with rice water stool, the intestinal contents are free from bile, thought that the exclusion of bile from intestine formed a condition sine qua non for the success of the experiment. They introduced pure cultures of comma bacillus into the duodenum, having previously tied the bileduct and were thus able to produce in a certain proportion of cases the classical symptoms of Asiatic cholera. The observers themselves believed, that the success and failure of their experiments depended on the presence or absence of bile. But the experiment succeeds equally well without any ligature of bile duct, and cultivations of comma bacillus grow as luxuriantly in media containing bile. Again, we know from our experience of the disease, that the hypothesis of bicarbonate as to the exclusion of bile is by no means true, for the secretion of bile stops only when the symptoms increase in severity, and when other secretions (urinary and gastric) likewise cease. On the other hand, the greater the injury to the intestine, the larger is the success in the experiment.
and Koch was perfectly justified in ascribing the death of the animals, not to any specific action of the Comma bacillus, but to the injury and maltreatment of the intestine.

In cases of injection into duodenum, the gastric digestion is avoided but nevertheless the injection did not always succeed. Therefore there is yet another factor requisite for the success of the experiment, and it was the nature of this missing link, that Koch now endeavoured to ascertain.

He neutralised the acidity of gastric juice by soda, and sometimes after administered a pure culture of Comma bacilli. Of 19 animals thus treated only one died with choleraic changes in the small intestine. This animal had alteration a short time previously, and its abdominal walls were very relaxed, and Koch thought that in some way intestinal feristalsis had been interfered with, and thus opportunity afforded to the organisms of gaining foothold and multiplying in the intestine.
According to him therefore, the second factor necessary for the success of experiments was the stoppage of intestinal peristalsis.

Röck now began another set of experiments, which notwithstanding the controversy that it has given rise to, still continues to be one of the most classical experiments recorded in the annals of bacteriology. And for this reason, we will deal with it, in extenso.

He administered to guineapigs 5 ccm. of a 5% solution of sodium carbonate (by means of a pharyngeal catheter), in order to neutralise gastric juice, & the contents of stomach. Next a moderately large amount of opium was injected immediately into the abdominal cavity, (generally one gramme of Tincture of Opium to every 200 grammes of body weight is necessary). The absorption of opium from the stomach of guineapig is an extremely slow process, and therefore the injection becomes a necessary precaution. Now if this is done in a particular method, every possible source of error
can be eliminated. The back of the animal, is grasped with the left hand in such a manner that its abdomen is projected forwards, and then the syringe is rapidly flushed into the abdominal wall. In this way, intestines are flushed to one side, and escape injury.

The animals however bear this manipulation with impunity: they become somnolent, lie down to their side and fall into a deep narcosis from which they waken in about half an hour, shortly to become as merry and frolicksome as before. Immediately after the opium injection and while the animal is still in an astatic state, the frote is again introduced and 10 c.c.m. of a cholera stool culture is injected. The animal soon recovers, but very soon begins to show signs of discomfort, refuses food, is affected with marked coldness and by flaccid weakness of posterior extremities, and usually dies after 48 hours. On post mortem
examination small intestine is found much reddened, and filled with watery fluid containing almost a pure culture of cholera commas.

The infective material can successfully be transmitted from animal to animal. If instead of cholera bouillon, the intestinal contents of a guineapig which had died of cholera, are administered to other animals, the latter also succumb to cholera. If Fisch, Prior and Denkè's vibrios are similarly injected, only a small proportion of the animals die, but all the survivors are killed on subsequent inoculation with comma bacilli.

Attempts have been made in other ways to set up in intestine a condition favourable to the development of comma bacilli. The administration of croton oil, or castor oil, or injection into the abdominal cavity of surfeintine or alkalise have given successful results. Alcohol, however, has answered best.
It has been objected that the symptoms of experimental cholera lack the very essential factor of intestinal disturbance, and that guineafogs perish without having vomited or passed watery evacuations. But guineafogs do not vomit, and the absence of diarrhea, is probably due to the extraordinary size of their cecum, which is capable of retaining considerable quantities of intestinal contents.

It may be noted however, that the post-mortem appearances are not unlike those of true cholera.

But the doubting critics may still refuse to accept the causal relationship of Koch's vibrio, as the above named symptoms do not bear any resemblance to those of human cholera. But one may as well say, that the Pneumococcus of Frankel is not the cause of human pneumonia, because in rabbit and mouse, it produces a septicaemia instead of an affection of the lungs, or that the bacillus of Eberth is not the agent of Typhoid Fever, because
one cannot produce this disease in lower animals.

An objection of far greater weight, however, comes from Klein who has clearly demonstrated, that these very symptoms and anatomical changes follow the intraperitoneal injections of various other organisms e.g. Finkler's virus, Bacillus coli, Bacillus prodigiosus e.t.c. He believes that the living comma bacilli even if introduced in large numbers into the small intestine are quite innocuous, but capable of great multiplication if the intestine is pre pared from some cause or other diseased; the chemical products of cholera vibrios then act as poisons, analogons to the stomach obtained from other futtrefactive bacteria.

Gamaleia artificially increased the virulence of cholera bacilla by passing it through a series of guineafogs. With the microbe thus prepared, she was able to produce in dogs a disorder identical to cholera.
Recently it was observed that feeding marmots with cholera organisms and thereby produced all the classical symptoms of the disease and death of 50% of animals.

Of far greater interest however are the well known researches of Metchnikoff. In experimenting on different animals he entirely failed to produce cholera, although vibrios were largely present in the intestines. Even animals very sensitive to subcutaneous or intraperitoneal injections, enjoyed an immunity against commas introduced by the mouth. Was this immunity due to the influence of intestinal flora? By a series of observations on plate cultures he found that cholera vibrios were very sensitive to the influence of other organisms — thus e.g. Sarcina 4 torula favoured their growth, whilst Bacillus xylophilus restrained it. Guided by the fact, that for several weeks the intestinal tract of newly born rabbits is very poor both in quantity and variety of microbes it contains, he fed young suckling rabbits on small quantity of cultures of comma bacilli. Result
was that rabbits so treated were affected with true intestinal cholera. Further by mixing commas with tolua and sarcoa a very rapid infection with cholera was induced. Infection can also be brought about by introducing the organisms through milk, as may be done by soiling the teats of mother with cholera stools. When the suckling stage is passed, and animals begin to feed on grass, the results are far less satisfactory.

Guineafogs a few days old were also found sensitive to the same kind of treatment, but the intestinal cholera produced was far less characteristic and besides had a greater tendency to become generalised into the system.

It must be confessed that these experiments of Metschnikoff and Sabinotny, interesting as they are, can scarcely be convincing owing to the special nature of the animals employed. For are the experiments on guineafogs of any value, because the same symptoms and lesions can be produced by
various other bacterial forms. In fact, nothing has been produced in animals which can be said to be at all definite or specific of the cholera germ. According to Trenchow, any organism is capable, under certain circumstances, of causing death with symptoms and pathological changes more or less like cholera. The bacillus comma of Trenchow, which is sometimes found in the fur scraped from a dirty tongue, kills mice in 48 hours, and rabbits and dogs in a very short time when the dose is large. Again, bacillus coli comma when injected into the veins of rabbits kills them with symptoms of violent diarrhea and fever.

But, although the success in the experimental production of cholera, would have afforded us an important link in the chain of evidence, its failure cannot shake our faith in the causal relationship of Cholera comma. We know that lower animals are immune against cholera, as they are against Typhoid. Is the organism of Typhoid not the cause of Typhoid fever, because we have hitherto failed to produce this disease?
experimentally in animals. Therefore it does not appear reasonable to expect positive results in the case of Cholera. But we go further, and say, that experimental proof is not necessary, if it can be shown that cholera virus always go hand in hand with the infective material of the disease, and if this occurrence invariably corresponds to the pathological changes in the body, and to the course of the disease. That such a state of things actually occurs, has been demonstrated already, and in the absence of experimental cholera, is as strong an evidence as can be expected.

Experiments on Man.

One of the best known instances of accidental infection in man, is the alleged case of Koch’s assistant, who got a typical attack of cholera with abundant vibrios in his stools. There was no cholera in Germany at that time, and there was a distinct evidence of accidental infection in the laboratory. The case of Dr. Orgel of Hamburg may also be mentioned, but in this instance the result
was fatal, as a result of infection produced by sucking up some peritoneal fluid containing comma bacilli. The case described by Macnamara, who saw 5 persons out of 19, succumb to cholera, after drinking contaminated water cannot be regarded as conclusive, because there is no evidence that pure cultures were used, and the result must therefore be due to mixed infection.

On the other hand, nearly 20 cases have been reported who swallowed pure virulent cultures of comma bacilli, but though various symptoms followed not one of them died of cholera. But this is in accordance with the fact, that not every one exposed to cholera infection is attacked. We hold that one affirmative case is more valuable than many a negative. Besides no one has yet ventured to swallow the "virus exalte" of Haffkine.

A more convincing proof however is that, which is afforded by the results of Haffkine's anti-cholera vaccination. He has found that in Calcutta the mortality among the inoculated was 17.24 times less, and the incidence of the disease 19.27 times
less than among the non inoculated. If future results prove as satisfactory as these, they cannot fail to dispel many a doubtful point in the etiological role of comma bacilli.

**Cholera Vibrioc, as a parasite and Saprophyte.**

The vegetative activity of comma bacilli is much more active when they are in contact with air, but they do not cease to multiply when the supply of oxygen is cut off (as in intestines). If some nutrient jelly inoculated with cholera comma be placed under the receiver of an air pump, and a control tube placed outside, it will be noted that the former does not grow, while the latter grows as usual. But the organisms are not destroyed in anaerobic conditions, for if afterwards exposed to the action of air, they begin to grow again.

If grown on alluminous substance, with complete exclusion of oxygen, cholera poiso is produced much more energetically than
under the ordinary conditions of aerobic cultivation. This is due to the fact that much larger quantities of albumin are split up to meet the energy requirements of the organism. Such an experiment is naturally performed in the human intestines, where the toxines thus elaborated lead to the rapid intoxication of the individual.

Therefore comma bacillus appears to have a sort of physiological alternation of generations:—

(a) In the aerobic condition it vegetates more freely, but secretes less of its poisonous products.

(b) In anaerobic condition (as in intestine) it secretes toxines of a high degree of virulence.

Thus we find cholera organisms first in human intestine, existing anaerobically, actively secreting their toxines. When voided in defeca, they are extremely susceptible to the action of various germicides. Should they however escape unharmed, they thrive aerobically—in water supply e.g.—thus reacquire their energies sufficiently to face the difficulties of an anaerobic phase of existence, in a fresh individual.
Criticisms.

Socrates - Are there not thousands upon thousands who whenever you form a judgement, take up arms and have an opposite judgement and opinion, declaring that you judge falsely?

Theodorus - Yes, indeed, Socrates, thousands and tens of thousands, as Homer says, who give one a world of trouble.

We will now deal with the various criticisms, which have been applied to Koch's work. No one now seriously denies the causal relationship of comma bacillus. Even Pettenkofer, the most consistent of all opponents, is forced to admit that Koch's vibrio is the cause of Asiatic cholera. But it has been found that cultures obtained from different localities have shown great variations in their characters, further organisms apparently similar to Cholera vibrio have been cultivated from sources other than cases of true cholera.
Pettentrspfer's theory.

It has been observed, that not only under exactly similar conditions of traffic, do certain localities suffer most unequally and some not at all, but also that places susceptible to cholera are not only at certain times, but that some places are attacked more often less frequently, although this difference could not be attributed to a difference of traffic.

Hence it appears that in addition to the specific germ which is connected in some way or other, with human traffic, there must be another element,— Geographical situation—which is not present at all times, nor in all places. It is this element which acts as a local stimulant in the growth of comma bacillus, and without which no development of the organism can take place.

As Pettentrspfer graphically puts it—“the cholera germ (X) produces, on the ground of local and temporal disposition of the soil (Y), the cholera poison (Z), just as the torula cerevisiae (X) produces from the sugar solution (Y), the poison of inebriating alcohol (Z).” Individual predisposition is also held to be an important
etiological factor. Pettenkofer contends that comma bacilli are not always virulent, and that having once entered the human system they do not necessarily give rise to an attack of cholera. To him, therefore, all measures directed merely to check the diffusion of comma bacilli are unnecessary and unreasonable. According to the tripartite theory of the "localists," "y" is the more important factor, and every attention should be paid to it. The "contagionists," on the other hand, regard "y" as subsidiary to "x," and often negligible.

Rejecting the experiment upon animals owing to their antiquity, he experimented on himself at Munich, with pure virulent cultures sent from Hamburg, having previously neutralised gastric acidity with soda solution. He took no medicine, and in no way altered his diet or mode of living. Nothing happened for 48 hours, when the first symptoms of intestinal irritation appeared, and all these passed off in the course of a week. Numerous commas were detected in his urine. Pettenkofer, speaking of this experiment, makes such pertinent observations.
that no apology is needed to quote them in extenso—

"Nearly all bacteriologists are agreed that comma bacilli cause cholera, not by entering into the general organism through the intestine walls, but by remaining in the bowel there elaborating certain products which on absorption give rise to the infection. If a quantity of poisonous products, must have accumulated during these days in my intestines, from how millions of comma bacilli! And, yet I enjoyed good health, I had a good appetite, I never had symptoms of auto-intoxication. I had neither sickness, albuminuria, nor collapse. I was able each day to fulfil my duties. I concluded that comma bacilli certainly gave rise to diarrhoea, but that they do not cause either European or Asiatic cholera. Had my experiments been performed at Hamburg it might have been fatal, because on that day there existed in Hamburg, alongside of the Asiatic germ ‘x’, some Hamburg ‘y’, in sufficient quantity, to cause cholera even with a minute amount of the said ‘x’.

Emmerich performed similae
experiment on himself with like results.

But apart from these experiments, Pettenkofer points to the Hamburg epidemic itself, and recalls the abnormal climatic conditions of the summer of 1892, the small rainfall and the extremely low level of ground water, and contends that it was the pollution of Eölle, which by its constant ebbs and flows, impregnated more and more each day the subsoil of Hamburg. He moreover fails to give a definite answer to the very pertinent question as to how much the undisputed pollution of Eölle directly affected the inhabitants of Hamburg in consequence of its having been a source of drinking water, or as to how much it indirectly affected them by fouling the subsoil water and soil generally. The epidemic of Hamburg, on the other hand, is almost fatal to the localistic doctrine of Pettenkofer, as numerous instances were observed in which one side remained free of disease, because horses were supplied with water from Altona, while the other side was decimated by the use of specifically polluted water from the Eölle.
With regard to the self-inflicted experiments of Pettenkofer and Kommerich, if they were performed to prove that cholera vibrios are not always fatal, we say, that these experiments were performed unnecessarily. For it is a matter of common observation in the course of epidemic cholera, that while some are affected with the disease, others invariably escape. On the other hand these experiments definitely prove that at least some of the symptoms of cholera are caused by the vibrios. But it also appears from these experiments, that some other factor besides the essential germ of cholera, is also necessary, as notwithstanding the fact that particular care was taken in favouring their growth, both observers failed to get true cholera.

What then is the nature of this missing link? Pettenkofer is not very conclusive on this point, and his observations are more or less ill-defined. Having discovered a relationship between the frequency of the disease and the varying levels of ground-water, he thinks that the conditions of soil most favourable to cholera germs are, the moisture of soil and the presence of organic matter.
To emphasize this 
and to explain the favouritism
of cholera for certain houses, instances are
given of gas escaping from the pipes in
a street, passing through the soil and the
foundations of a house, and affecting the inmates
at some distance from the leak. The actual
decomposition with the formation of marsh gas,
which goes on in a soil filled with vegetable
refuse, is often remarkable, and the distance
the gas travels may be exceedingly great.
Pettenkofer thinks that in this way cholera
poison (like gas) may affect the inmates of the
house. The idea of such an escape of cholera
poison can scarcely be entertained in a
country like India, where people mostly lead
an outdoor life during the usual cholera
season. We know of several instances in
which cholera falls with such severity
on houses (with good sanitation and pure
water supply), that unless their inmates
leave the place, every one of them succumbs
to the disease. While we do not deny that
"inhalation" may be an occasional factor in
such cases, we think that a more rational
explanation lies in the pollution of household
water supply, caused by the cholera organism, while passing its saprophytic stage in the soil of that locality.

The epidemics which have occurred on board crowded emigrant ships, and the great liability of persons who wash cholera infected clothes to be attacked with the disease, show that cholera can be induced without any growth in the soil. It will be interesting to note in this connection, that in no cholera epidemic has this organism been isolated from the soil. But this may be accounted for by the fact, that it is exceedingly difficult, if not impossible, to isolate such a delicate microorganism as comma bacilli, from a soil teeming with countless bacterial forms. Although this organism has never been found in the soil, many observations have been made regarding its behaviour and fate when introduced into soil samples. \(^{(15)}\) Dempster's experiments indicate that (1) in dry soils, evaporation not prevented, comma bacilli were alive on the 3rd but dead on the 4th day in wet sand.
and in garden earth; (2) with a moist soil evaporation not prevented they were alive on the 7th day in the sand and on the 33rd day in garden earth; (3) when evaporation was almost prevented they were alive on the 28th day in the sand and on the 68th day in garden earth; (4) in dried soil they did not live longer than one or two days.

The degree of moisture, therefore, appears to be an important factor in regard to the retention of the vitality of these organisms in soil. These facts, indeed, find ample corroboration in India and enable us to explain the endemic and epidemic prevalence of cholera. Thus in lower Bengal, the soil is always moist and the disease is endemic, but is lessened during heavy rains when the soil becomes saturated. In the Punjab the soil is dry, and epidemics do not occur, unless some amount of rain has fallen. In the former case, rain by occupying the interstices between the solid constituents of the soil, interferes with the soil ventilation and thus brings about the "suffocation" of the cholera germ.
In the case of Punjab, on the other hand, rain supplies the moisture necessary for the revivification of comma bacilli and thereby favors the occurrence of epidemics.

It follows, then from what has just been said, that in India at any rate, soil plays an important part in the diffusion of cholera. The particular kind of soil, in which comma bacilli can best pass the aerobic stage of their existence, are the loose and partially moist sands in the beds of rivers, and along the sides of tanks and wells. While the connection between soil conditions and cholera prevalence, is true for some localities, the evidence is not sufficiently strong to warrant its universal application. In fact, as will be discussed later, the prevalence of disease is largely dependent upon other and more important factors than soil.
Cunningham's Criticisms.

Instead of searching for commas in other diseases, he has confined his attention to the kinds of commas, which are found in case of cholera. He denies the vibrionic unity of cholera, and contends that—

1) he has seen undoubted cases of cholera without the presence of any commas.
2) the vibriones separated from other cases were not of one but of various species—distinct morphologically, chemically, biologically.
3) in one case, he separated three distinct species.

Cunningham deals only with fresh evacuations, and therefore the differences noted, are natural differences and not due to artificial conditions. The morphological distinctions are constantly associated with other differences, and are not only persistent but persistently associated with the same differences. Each organism is subjected to the same treatment, and the nutrient media are maintained unchanged. The different modes of growths are very striking. Precisely similar differences are observed.
in cultivations made in England. This shows that the distinctions are not merely temporary variations, but are permanent differences maintained under conditions of growth materially changed. Klein uses a different nutrient gelatine preparation, and grows the bacilli on different potatoes in London, under conditions very different to those which prevail in Calcutta in July, yet each bacillus breeds true under its changed environment, the same bacilli grow exactly in the same way in London, as in Calcutta; and exhibits the same characteristic appearances by which it is distinguished from the others which accompanied it. Further, continuous growth in artificial media leads to no assimilation of characters.

Cunningham contends that if these morphological & biological differences which commas exhibit, are mere differences of varieties & not of species, the same reasoning applies to Finkler's comma, which must along with other varieties be recognised as a variety of Rock's comma. If these differences be specific, it is impossible
that all these species should be the cause of a well marked & specific disease, such as cholera.

It will be readily seen that Cunningham’s observations do not prove anything more than that comma bacilli are susceptible of immense modifications, both in their morphological & biological properties.

But we are aware of such permanent variations, being exhibited in the case of other microbes. Thus Bacillus Prodigiosus may be changed from the small bacillary into a permanent long bacillary form, & the entire bacillus may be converted into an asporogenous species. Similarly variations in virulence are also observed. The organism of pneumonia if continuously grown on ordinary media very soon ceases to be virulent & this loss of virulence is permanent. Again the diphtheria bacillus may be made to lose its virulence by growth in agar agar. The differences between the sporeogenous & asporogenous varieties of Anthrax bacillus, are certainly more profound than those, observed in the divers species.
of Cunningham. Unless it is shown that they possess different pathogenic properties, we cannot class Cunningham’s 13 commas as as many distinct species. In the interests of Bacteriology itself, it would be best to regard the different forms of microbes as belonging to the same species, provided they produce the same disease. We are inclined to regard the various vibrios of Cunningham as nothing more than the degenerated (or unregenerated) varieties of Cholera microbe. of Koch.
Other Criticisms.

There is yet another kind of criticism which remains to be discussed. It is that vibrios closely resembling Koch's organism, have been cultivated from sources other than cases of true cholera. Thus Lewis has found such vibrios in the mucus of mouth; Miller in decayed teeth; Denkë in old cheese; Liguéard in a case of dysentery; Gamaleia in intestinal contents of poultry affected with chicken cholera; & Klein in the intestines of guineapigs, & in diarrhoea of monkeys. Of special interest in this connection are those cases in which comma-like vibrios have been found in drinking-water or sewage of communities, who were not suffering from cholera at the time. The varieties mentioned are too numerous to be detailed in the limited space at our disposal, & we must be content with a brief reference to a few of them:

1) Koch found these comma in a tank at Calcutta, at a time when persons using it were free from cholera.

2) Vibrio Berolinensis found by Reisser in water which had previously contained
Cholera vibrios. It resembled comma bacillus in morphological & pathological properties, but gelatine plates were not visible till 48 hours.

(3) Heider isolated from the water of Danube a vibrio (Fibris Danubianus) very similar to the former in its properties. By cultivation in Laboratory for sometime its liquefactive power is about equal to that of Finkler's organism.

(4) Spirilla like Koch's were found in bile at Hamburg by Randel, six weeks before cholera appeared in Hamburg.

(5) Recently Sanarelli has isolated about 32 vibrios more or less resembling Cholera Spirillum from the drinking water at Versailles. They were of extreme variability—some gave indol reaction, others did so after a few days & the remainder not at all. The vibrios which at first gave no evidence of pathogenic power when carried through a series of animals caused a fatal infection. An animal protected against any one of these is not necessarily proof against the others.

These statements open up questions of great etiological importance. How are we to distinguish Cholera vibrios from
other vibrios? Is cholera process due to one organism capable of showing great variations or is it caused by several species of vibrios?

Diagnosis of Cholera Spirillum.

Vibrios isolated from cases of true cholera exhibit in themselves, great variations both in their microscopic appearances and in their growths on ordinary media. Thus comma bacilli may sometimes liquefy gelatine as rapidly as Metschnikoff's or Finckle's Spirillum and may even fail to respond to the "cholera red" test. Again it has been shown that occasionally inoculation of fowls with cholera comma does give positive results; this test therefore can no longer be relied on to distinguish Metschnikoff's from Cholera Spirillum. Nor can the presence of a single flagellum serve as a reliable test, for in several cases, cholera commas have been observed to possess more than one.

Rumfel has shown that comma bacilli after being passed through fowls & cultivated in artificial media develop phosphorescence.
Therefore the presence of phosphenes, is no longer held to be the sole monopoly of water viriles.

1) Grübler lays great stress on the character of colonies in gelatine plates (vide ante). But inasmuch as this test fails in the case of Denke's organism, it cannot be said to have any specific value. Again the difficulties connected with it are by no means few. The gelatine employed must have a special composition, and the temperature must be kept constant between 20° and 22°C. Moreover the distinguishing characters make their appearance only at a certain stage of development.

2) Of late much importance has been attached to the so-called "cholera red" reaction. It depends on the formation of nitrosindol, and occurs when concentrated sulphuric acid is added to a cultivation of comma bacilli in broth or peptone. A reddish colour appears at once, or at the latest within a quarter of an hour. (To ensure this reaction, peptone used, must be pure, and sulphuric acid should be free of nitrogen).
But every kind of cholera vibrio does not give this reaction, and on the other hand, many water vibrios unconnected with cholera give it quite as well as Koch's comma. This test therefore is perfectly useless, and has no specific value whatever.

3) Pfeiffer has introduced a novel test, for distinguishing between true and false cholera vibrios. The test is based on the well known law of Behring that the serum of a protected animal is specific in its action; that is, if injected into an animal it confers on it an immunity only from the leasion against which the original animal had been protected. He injects a mixture of anticholera serum with the suspected organism; if the animal succumbs, the organism in question cannot have been a cholera germ; if it survives, the organism is choleraic.

The organisms of cholera so markedly differ from each other, that it is but natural, that the results with Pfeiffer's test should vary, according as one or other of these vibrios is taken as our standard
of comparison. But supposing for the sake of argument, that true and typical vibrioid are selected, it is highly probable, that they may be so altered in their properties (after being kept in the laboratory), as to show a series of gradations in the intensity of reaction, and may even react negatively.

Pfeiffer's test involves an assumption (which has yet to be proved), that morphological and cultural differences are never accompanied by chemical variation. Sanarelli denies the absolute specificity of protective serum, since he succeeded in conferring an immunity on guineapigs against choleraic infective, by means of antityphoid serum.

Notwithstanding these apparent drawbacks, we hold that the positive test has a distinct diagnostic value. Where the test responds negatively, we cannot definitely say, that the organism in question, is or is not a true cholera vibrio.
Variability of Comma bacilli.

Well marked variations of comma bacilli have been observed in simultaneous epidemics in different localities, and Cunningham has shown, that there are variations not only in various cases, but also in the same case. Therefore the rigid monomorphism attributed to comma bacilli, must be abandoned and we must admit, that the organism is highly pleomorphic in its characters. Cultivations on ordinary media show, that cholera vibrios are capable of immense modifications, both in form and cultural peculiarities. That which is possible with a few test tubes can be done far more effectively in the wonderful laboratory of nature. It is now admitted by most observers, that typical comma bacilli when kept in water differ more from one another, than non-choleraic vibrios. Recently Klein by a series of observations on oysters kept in sea water tanks, to which cultures of typical cholera vibrios had been added, has found, that permanent alterations of the characters of vibrios could thus
He established.

Hankin contends that the discoveries of vibrios in water and elsewhere throw doubt on the tests of cholera vibrio, rather than on its authenticity as the cause of cholera. He regards the many varieties of vibrios, as degenerate forms of Koch's comma. It is no argument to say that a water vibrio is not choleraic, because the consumers of that water do not suffer from cholera, for as will be presently shown, several other factors must also operate before the disease can be produced. Unfortunately we cannot accept Hankin's researches as at all conclusive, as he relies for his experiments on guineapigs, which, as we have already seen, are of a very doubtful value.

In the present state of our knowledge, it seems scarcely possible to reconcile the conflicting statements of various authors. Even human dogmatism stands staggered and abashed, in face of these mutual contradictions. We cannot therefore be tempted to enter into all the seductive
hypotheses to which scientific enthusiasm gives expression: "from enthusiasm to infatuation the path is ferocious and slippery." But we shall endeavour to offer a basis for conciliation between the different schools of thought. The whole controversy forcibly reminds us of the celebrated discussion as to the colour of the chameleon, in which as now, each observer saw and spoke from his individual experience. The question is, "may they not be all right? may we not likewise, regard the various commas as comprising one group, or rather one series, in which Lewis's and even Finkler's commas, may find a place side by side with the Cholera organism? It would no longer be reasonable to exclude Finkler's comma, because it differs in certain particulars from Koch's vibris, nor, as has been mentioned already, cholera organisms differ much more among themselves in the very same particulars. We may regard the innocent comma of Lewis, merely as a degenerated variety of the Cholera microbe, capable
of thriving in its attenuated condition, in the normal alkaline saliva. In such a series, too, Koch's commas may be arranged according to their various gradations in virulence. We will then be readily able to understand why some commas may be perfectly innocent, others may give rise to diarrhoea, and yet others to malignant cholera.
Etiology.

Cholera being an intestinal disease its organisms are mainly found in the objects of patients outside intestines, the microbes retain their vitality for a long time, as they remain capable of development in a moist condition for months. They do not fall a prey to the resulting putrefaction because man who throws the excreta into water dilutes them as much as possible, transfers them with his fingers to the new media, soils the linen with them, and thus offers the bacilli protection from harm, and opens up numerous channels for the spread of the disease.

Thus the disease can be transmitted by food, drink, moist linen, flies, cholera excreta. Man himself may carry the infection without this betraying the slightest sign of the disease (except, of course, the presence of cholera commas in defeca). Neither merchant nor postal service have been known to carry the cholera poison. The disease is generally not contagious, although a few instances point to such a possibility.

The infection can't possibly
be inhaled because the cholera organism is not rapidly killed by drying. Comma bacilli which are capable of development, can only be transported through air for short distances, when infective fluids are agitated and bubbles are detached, e.g. when waves strike a quay or when cholera linen is washed. In these cases small bubbles of fluids containing bacteria, may be brought by currents of air into contact with predisposed individuals. While admitting the possibility of such cases, we hold that the contagium vivum is, in a much larger proportion of cases, swallowed by the agency of food and drink.

Waterborne Cholera.

We have already seen, that the epithelial lining of human intestine is the nidus of the cholera germ, and affords conditions which are so favourable for its growth and reproduction. Now we know, that intestinal epithelium is constantly shed, and forms a considerable part of normal alvine discharges. Thus when water becomes infected with cholera bacilli,
it not only contains the essential organism of cholera, but intestinal epithelium as well, and the latter affords to the former facilities for growth and multiplication, similar to those presented by the intestinal epithelium in situ. The danger of cholera tainted water, then, is twofold:

1. The vibrios are rapidly reproduced in such water.
2. If taken into the system, it is brought into contact with intestinal epithelium — the nidus in which it grows and on which its action is specially manifested.

These theoretical considerations are amply borne out in almost every outbreak of cholera. We have often observed sudden outbreaks in Indian villages, and have been struck with their absolute limitation to the consumers of the infected wells. Those using the non-infected wells remain remarkably free from the disease, and this mapping out of the two sets of inhabitants, is as interesting as it is instructive. When the infected wells are stopped, no fresh cases occur, and the outbreak rapidly dies out.
To any one familiar with the ordinary sources of water supply in India, and the numerous ways by which they can be polluted, it must be apparent, that Cholera is mainly (if not entirely) propagated by water. The outbreak in connection with Broad Street pump, and the Cholera epidemic of Hamburg, may be mentioned as two classical examples of waterborne Cholera. Again, if we look at the remarkable decrease of mortality, which has followed the supply of pure water in the endemic area (e.g. in Calcutta), the evidence is even stronger. We will not go further into the matter, as this question has now well nigh passed beyond the range of controversy. Perhaps now and then, an unyielding critic appears on the scene, but like the naughty boy in the Punch, who challenged “no Brewery” and ran away, the writer of “no Waterborne Cholera” and makes good his escape.

Cholera from other Sources.
comma bacilli grow very luxuriantly in milk in which they give rise to no noticeable alteration.
It may therefore be well imagined, how deadly milk can be under such circumstances. Dr. Simpson in Indian Medical Gazette, records an instructive case, where on board a ship (at Calcutta) ten persons partook of milk supplied by a milk seller, of these four died of cholera, five suffered from severe diarrhoea. The tenth who escaped had taken only a small quantity of milk. On investigation it was found, that milk had been adulterated with water obtained from a tank, to which choleric defeces had gained access. But particularly interesting was the fact, that none of the other members of the crew were attacked by diarrhoea or cholera.

While discussing the vitality of comma bacillus, we have referred to the innumerable media on which that organism can thrive. It may therefore be well imagined, how numerous are the ways by which the poison can be introduced into the system. In this connection, we cannot emphasize too strongly the importance of vegetablist's fruit, as disseminators of cholera in India. The vegetables exposed for sale in the bazaars,
are commonly sprinkled with water from filthy tanks or fountains, and the growth of cholera organisms is thereby admirably favoured. But not only these uncooked vegetables offer a nidus for their growth, but they often produce that condition of slight indigestion which, along with an overloaded stomach, is so favourable for the development of comma bacilli in the human alimentary canal.

**Flies.**

Leaving to the proximity of latrines to cow-houses, or also to the manner in which food is openly cooked and exposed for sale in India, it is easy to understand that flies cannot play an important role in the dissemination of cholera germs. (2) Haffkine has demonstrated that sterilised milk might become contaminated with cholera organisms, if kept in an open jar to which flies had free access, in a locality infected with cholera. But we must note in passing, that this is not simply a case of the transference of cholera germs from defecata to the food, as the latter actually multiply during their passage.
through the intestinal tract of flies. Specific bacilli in all their virulence have been demonstrated as late as the 4th day, after feeding flies with pure cultures.

If some flies be coloured with an artificial dye, it will be noticed that they can follow man for comparatively long distances in his various travels. It seems to us therefore, that the part which flies play in the propagation of cholera, runs parallel to that of man, although it is of a very secondary importance. But while man by polluting the general water supply may give rise to an epidemic, flies, on account of their infecting food and milk, can only be concerned in the causation of sporadic cholera.

Individual Redispersion. With all these numberless ways in which cholera poison can find its way into the system, it does seem singular that not every person infected is attacked with the disease. This is due to various factors, which may be summed up under the
name of individual predisposition. There is first of all, the benign influence of hydrochloric acid in the normal gastric secretion, which as we have already seen, is so highly prejudicial to the vitality of comma bacillus. But this action, unfortunately is not invariably exerted. Water, unlike solid food, cannot stimulate a copious outflow of gastric juice, so that the infected water would pass through the pyloric opening, even before the gastric reaction has become acid. Assuming that the specific organisms pass unscathed through stomach, they still have to contend against the intestinal flora, which are concerned in the processes of healthy metabolism. And lastly, the energy of cells and their resisting powers towards the toxic products of the organisms, may come into play. Such then are the ways in which the protective arrangements in healthy body may operate, and the results of the ingestion of the poison will vary, in proportion as this resistance deviates from the normal. Thus in some cases, there
may be no disturbance, in others slight diarrhoea and in others again, a serious illness. Perhaps in this way some people may acquire an immunity from cholera. That small doses of infection frequently repeated, induce some temporary immunity is demonstrated by the comparatively low mortality in its endemic foci. And it is owing to the lack of such an immunity that recent arrivals in an infected locality are so frequently attacked with the disease. But in these cases, fatigue also acts as an important predisposing factor. For we know, that white rats which are very insusceptible to anthrax, becomes markedly susceptible to this disease, if it is made to work a treadmill in a cage, until it is thoroughly fatigued.

It would be interesting to add that in the non endemic areas in India, the season of cholera almost coincides with the season of "natural diarrhea". During these months, the force of infection becomes enormously multiplied and the vitality of the people lower the
natural resistance of the system. Unripe or decomposing fruits are devoured in large numbers, and hence the popular adage that cholera will be bad, when melons are cheap. Purgatives are freely indulged in, and intestinal catarrh is courted by deliberate exposure to nocturnal chills. The pollution of tanks reaches its maximum, and the countless number of flies are free to play their noxious role in the disseminator of the disease. All these influences, operating on an intestine already rendered unhealthy by malarial dysentery, cannot but precipitate an intestinal disease like Cholera.
Sporadic Cholera.

By this we do not mean those cases which form the "aura" of a commencing epidemic. The difficulty in explaining such cases lies not in the undisputed role of comma bacillus, but in the fact that the chain of infection is apt to be lost through the mazes of Indian social life. If this point be borne in mind, we will then be able to explain many of the so-called mysterious cases of sporadic cholera. To any one who has seen the filthy and slimy layer of the interior of mussakk (water skin) it must be obvious, that no better nidus could be afforded for the growth of comma bacilli. And so, the Indian water bearer unconsciously distributes death along with water. Again bottles of aerated water are generally cooled by inverting them mouth downwards in water, which is often dirty. It is possible, that some drops of infected water may adhere to the mouths of bottles and may also be drunk. Corpses of persons dead of cholera have also been known to give rise to a localized outbreak.
Again food (especially rice) may be spread on the floor of a room originally occupied by a cholera patient, and in this way become contaminated with the defaecation. The influence of flies, and of infected fruits, has already been dwelt upon in the preceding pages.

**Epidemic Cholera.**

The vast area comprised within the delta of Ganges in lower Bengal, is the seat of the home of cholera. Here the soil is very wet, low, and covered to a very high degree with animal and vegetable material, the decomposition of which is favoured by an average temperature of 86° to 100° F. A luxuriant vegetation, and an abundant animal life, are thus developed, and among these are the organisms of *Malaria* and *Cholera*. But if the soil is a favourable nido for comma bacilli, the human intestines in the endemic area are no less so, for they are already more or less diseased by repeated doses of dysentery, and are highly
charged with carbohydrates, especially rice. — the staple diet of the people of Bengal. Moreover the frequent indulgence in opium, ganja, and various spirituous liquors, induces in their alimentary canals, a condition not unlike that, which obtains itself in the intestines of guineapigs, after the injecting tincture of opium.

Every outbreak of epidemic cholera beyond the confines of India, may be traced back to its endemic home, through a continuous chain of human beings affected with the disease, or through articles contaminated with their dejecta. Cholera invariably follows the routes of human intercourse. It has never been known to extend from one place to another faster than man can travel. Whatever the specific poison may be, it can never spring up de novo in a locality, unless introduced by man or articles of clothing from an infected place.

Nearly all observers are agreed that large epidemics of cholera are mainly waterborne — cholera infected man and
cholera infected rags serving chiefly as links of connexion between the various water supplies. When Cholera germs are thus introduced into the water supply of an infected locality, they give rise to a widespread epidemic which however ceases as soon as the infected water is cut off. If however the germs do not gain access to a water supply, but are deposited in the neighborhood of dwellings of the people, they will only set up small and localised outbreaks.

On the other hand, we know of several districts in India, in which Cholera has reappeared as an epidemic, notwithstanding repeated importations of the poison. Thus Montgomery and Multan have never suffered from cholera epidemic, although they are in constant communication with places where the disease is endemic. During the last great epidemic of Punjab, we observed a case imported in Montgomery from Lahore, who gave the infection to two members of his family (we have very strong reasons for believing) by contagion. Five fresh cases occurred, and these three individuals sum up the cholera history of a district, in direct
railway communication with places where people were daily dying in hundreds thousand. Again steamers fly constantly between India and Calcutta, and yet the former have always enjoyed an immunity from the disease. It is evident then, that besides the pollution of water supplies there are other important factors, which either favour or retard the development of epidemic cholera.

**Conditions influencing cholera epidemics.**

(1) **Soil conditions.**

Speaking generally, proportions of deaths among the inhabitants from cholera is inversely as the elevation of the ground. But this rule is by no means universally true, as cholera has often raged with great intensity in the hill stations of Himalayas. The kind of soil best suited for the development of a cholera epidemic, is that which is porous, more or less charged with organic matter, and having its interstices filled with water as well as air. Such a soil is most likely to be found in the riparian areas, and this is why cholera generally follows the course of rivers.
(2) Seasonal influence.

In India, at any rate, we see the rise, culmination, and decline of epidemic and endemic disease, recurring at the same seasons, year after year, and we are bound to admit the influence of the season. But, at the same time, the very inexactness of this the many exceptions to a definite inexorable rule, its partiality and its uncertainty, drive us to the conclusion that the influence of seasons is no direct, but that it acts through some modifying medium. Unusual conditions of seasons and weathers may markedly modify the course of epidemics, but they cannot of themselves, give rise to an outbreak of the disease. We deny that

"Unusual times do breed unnatural trouble."

A certain amount of temperature is necessary for the saprophytic life of comma bacillus, but cholera is not always most prevalent in the hottest season, nor is it always stopped by winter. We have already seen, that while this organism is very sensitive to heat, it is extremely resistant to cold. The appearance of cholera
in the warm season is due to the revivifying influence of heat, on the organism paralysed by winter.

As regards rainfall, there can be no doubt, that it exercises a marked influence on cholera. It has been observed that in India, no extensive epidemic can occur unless during or after rain. On the other hand excessive rainfall may hinder the course of the disease by destroying the vitality of comma bacilli, firstly as the result of interference of soil ventilation, and secondly from their being carried deeper down in the soil, where the conditions are no longer favourable to their existence.

(3) General Sanitation.

General sanitary defects are conducive to cholera prevalence and mortality, especially by lowering the normal resistance, and by specifically polluting the air, soil, and water. Hence the disease falls with greatest severity on dirty towns, in filthy quarters, and on uncleanly people. Good drainage and good water supply, prevent cholera by
making it impossible for the defects of one to contaminate the food and drink of the other. It is owing to good sanitation that this country has enjoyed for so long an immunity from Cholera, and to the want of it, is due the marked prevalence and heavy mortality in the East.

Conclusion.

We will now wind up with some general remarks, our discussion of the causation of Asiatic Cholera. The classical researches of Ballard have demonstrated that diarrhoea presents some notable resemblances to Cholera. Marked prevalence of the former often precede the latter; while both appear to be associated with filth, and to be influenced by heat, and certain physical conditions of the soil.

Clinically, the resemblance is even more striking, for such differences as there are between the two diseases, are mainly differences in degree of malignancy. Again it is more than probable that in the endemic area at any rate, where the soil is so highly charged with the necessary organisms, Cholera (like diarrhoea)
is occasionally disseminated by direct emanations from the soil. These remarkable resemblances between Cholera and epidemic diarrhoea, naturally lead us to the surmise, that Cholera may after all be but an Asiatic variety of a disease, known elsewhere as diarrhoea or Cholera nostras. It is possible (if not probable) that the differences in locality, climate, and races, may have brought about profound differences in the malignancy etc. of the same disease.

We have already referred to the soil of Gangetic delta, as a favourite habitat not only for Choleraic, but also for malarial organisms. In this malaria presents a great resemblance to Cholera, for although both affections manifest a great tendency to become endemic in alluvial districts, there exist nevertheless many localities where both diseases are unknown, as for instance in the large swampy districts in South Australia. That Cholera also is unknown there, is commonly attributed to the circumstance, that India is far too removed to allow of the transport of infectious matter, but no one has as yet attempted to
explain the absence of malaria on such grounds. On the other hand, there are localities (like Andamans) which although markedly suffer from malaria, remain perfectly immune to cholera.

But with regard to their manner of diffusion, the resemblances between the two affections are still more striking. It is a matter of common experience, that removal from an infected locality is an undisputed remedy against cholera, and how often has it been observed that crossing to the other side of a river has sufficed to put an end to malaria?

We do not for a moment mean to imply, that we consider the two affections as mere gradations of the same disease; all that we urge is, that Cholera may have a telluric origin in some cases.

The striking resemblances between diarrhoea and malaria on the one hand, and cholera on the other, remind us not too forcibly, that the influence of soil in the spread of cholera, is
not so small, as the "water-fanatics" would have us believe. We say, that in proportion as this locality link in the chain of its requirements is granted to it, the powers of Cholera are at their highest and most deadly. For, Cholera is like the Apocalyptic beast, requiring both legs, (its local 'soil' relations) and wings — for transport (human, aqueous etc); take away one or the other, and you non plus it.
Prevention.

The problem of Cholera prevention shall remain unsolved, so long as we do not strike at the root of the whole matter. The battle of Cholera, must in the first instance be fought in its endemic home. The planting of eucalyptus trees and deep drainage of the delta can do much to render the soil unsuitable for the growth of the organisms of Cholera (as also of malaria). Similarly Haffkines preventive inoculation can make it impossible for them to gain a foothold any longer in the human intestines of that region. To grapple with an unseen foe is always a vain and hopeless task: all that we can do is, to so modify its habitat, that it may find conditions no longer favorable for its growth, either as a parasite or as a saprophyte. Whether this suggestion is ever to be acted upon, we know not; but for our part we are thoroughly convinced that until and unless all our energies are concentrated on the endemic area, the prevention of Cholera shall always remain a dream, never to be realised.
It is high time, that an Elementary Public Health Act might be enacted in India, and a distinct Sanitary Service organised to enforce it. Every town must be provided with an ambulance department, a free disinfecting station, and a hospital. No new dwellings should be erected unless approved by the town survey and the pollution of water supplies strictly prohibited. While a pure water supply is a highly important factor in the prevention of Cholera, we contend that drainage and sanitation are no less so. We may give people for ever so long the purest water— the “nectar of Hygiea”, to drink and yet we would scarcely be able to protect them from the ravages of this disease. Sudden spasms of periodic activity are totally useless: our efforts in the prevention of Cholera, must be ceaseless, systematic, and energetic. The entire framework of organisation must be ready before the epidemic appears, otherwise it looks like waiting for a conflagration before organising a fire brigade.
When Cholera actually breaks out, the city should be divided into wards, each under the control of, and in direct communication with, the Central Sanitary Office. The different sources of water supply, as well as the conservancy of town, must be carefully attended to. The infected wells need not be stopped, they should better be purified by the use of permanganate of potash. The importation of infected cases, must be restricted by careful examinations, and the ‘suspects’ detained in the so-called “observation camps.”

A system of house to house inspection should be instituted, and careful search made for cases of epidemic or diarrhoea. As soon as the diagnosis is confirmed, bacteriologically or clinically, the patients must be sent to the hospital, where they can be best treated.

In nursing cholera patients, hands and face must be scrupulously washed with corrosive sublimate lotion (1 in 100). Dishes and other utensils should be strongly heated in burning alcohol, and bread sterilized by toasting. The discharges of cholera patients...
are received in a vessel containing ferrous sulphate or corrosive sublimate. They must either be cremated, or buried deep in the soil, away from any source of water supply. In some parts of India, soil contains no nitrifying ferments which are of such use in destroying cholera germs, and we therefore cannot emphasize too strongly, the proper disinfection of excreta.

No one is allowed to leave the hospital, so long as convalescents are detected in his excreta. Convalescents before their discharge should be bathed in corrosive lotion, and their clothes carefully disinfected by steam. On emptying a ward, it is fumigated by sulphur dioxide for 24 hours.

While the authorities can do much to prevent cholera, much more can be done by the citizens themselves. Their duties in this direction, can be pointed out by leaflets, public lectures and so forth. A handbill suited for an Indian town must evidently be couched in popular and dogmatic language, and it is with this, but we shall conclude our brief observations on the prevention of cholera.
Handshill

(1) Cholera is present in the town. It is quite preventable; so, if you are attacked with the disease, it is entirely through your own fault.

(2) Always boil your water and milk. Do not use unboiled water even for cooking purposes.

If required, filter the water first, and then boil it. The following is a good and cheap filter:

Suspend three clean vessels, one above the other, in a triangular frame of wood. Half fill the top one with clean charcoal, and the middle one with sand (to the same extent). Small holes are made in the bottoms of these vessels, and filtered water collects in the lowest. Carefully protect the filter from bird droppings, insects, etc.

(3) Avoid unripe or overripe fruits, especially melons and cucumbers. Take that form of dietry, which experience has proved to agree best with you, lest on no account eat stale rice.

(4) Live a temperate, regular and occupied life.
(5) Avoid chills, but take moderate exercise daily in the open air.

(6) If your bowels are constipated, take some Castor oil, but avoid strong purgatives.

(7) Take a few grains of Sulphate of Quinine every morning.

(8) If you cannot (or will not) follow these directions, you must immediately remove to some healthy locality.

(9) Cholera is chiefly curable in the diarrhoea stage. As soon as the bowels are loose, put the patient to bed, give a dose of Chlorodyne, and inform the medical officer of the nearest station.

(10) Poison of the disease is contained in the stools, and therefore receive them in vessels containing the disinfectant provided by you for the purpose.

(11) See that your clothes & yourself are clean.

(12) Burn all dry refuse. Distinguish privies and drains with spirit and crude Sulphate of Iron (Heera Rasoo of bazaars). "Scavenge! Scavenge! Scavenge!"
References.

(2) Allbutt's *System of Medicine* vol. 1; p. 895.
(7) Wisselmann (same as #4).
(10) Koch's etiology of cholera translated by Laycock (papers read at conferences of '84 '85).
(14) Koch's "Cholera in Germany during '92-'93" translated by Duncan.

(16) Cunningham. Scientific memoirs by the Medical Officers of the Army of India. '85-'94.

(17) Sternberg's "Manual of Bacteriology" pp. 566-567

(18) Do Do pp. 569


(20) Hankin. Indian Medical Gazette March '95.


(22) Lancet. May 20th, '93; p. 1212.