

T H E S I S

on

THE VALUE OF MEASURES FOR THE PREVENTION OF  
THE SPREAD OF PLAGUE BY RAILWAY TRAFFIC  
IN INDIA

together with

a brief description of what experience has demonstrated to be the most satisfactory way of organising such measures.

An enumeration (with illustrations) of the principal features of the Plague bacillus for facilitating recognition.

and

a summary of the leading points which aid in the diagnosis of doubtful cases among passengers detained under observation.

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by

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P R E A M B L E .

From a survey of the epidemiological factors which have an aetiological bearing in plague, it would seem to be thoroughly established that plague infectivity as between human beings, and the infectivity of clothing or other personal effects are agencies of very great importance.

With regard to the first of these, the extent to which the factor is operative, in individual cases, is necessarily in direct proportion to the degree of opportunity afforded for the escape, from the infected body, of the infective agent. The chances of such escape are limited in cases in which the organism has not entered the blood stream, or has not infected the respiratory passages, or has not, in primary bubonic cases, gained entrance by a mucous/

mucous surface. Thus, ordinary uncomplicated bubonic cases resulting from skin inoculation are only infective to a slight extent, while the so-called septicaemic cases, pneumonic cases, and uncomplicated bubonic cases in which the point of inoculation is on a mucous surface, are so in a much higher degree.

Taking plague cases, generally, in such conditions as obtain in good houses, or places like plague hospitals, where circumstances favouring desiccation are encouraged, chemical disinfectants freely used, and other precautions adopted, the factor does not play an important part in the spread of plague; but the reverse is the case when the escape of the virus takes place under circumstances which are favourable for the preservation of its vitality. As, moreover, such escape may continue to occur for long periods after the establishment of/

of convalescence, as demonstrated by Cayley,<sup>1</sup> Gotschlich,<sup>2</sup> and others, it is not difficult to estimate how important a focus of infection even one case may become under suitable circumstances.

It is apt to be considered that rapidly fatal cases, though of highly infectious types, do not contribute in an important degree to the spread; but it must not be overlooked that enormous numbers of bacilli may escape from such, before death, into surroundings calculated to preserve their vitality and promote their proliferation.

As regards the infectivity of infected clothing or other personal effects, there are numerous instances on record which demonstrate that importation of infected clothing by people (themselves not infected)/

1. Evidence before Indian Plague Commission, vide Chap. iii., p.92 of Report.
2. Zeitschrift für Hygiene, 1899, p. 405.



ected) has given rise to epidemics in un-infected places, starting by rats becoming infected in the houses into which the infected clothing had first been introduced.<sup>1</sup>

Besides such particular instances, it has been common experience that plague has continued to occur among people after evacuation from infected villages or towns in cases in which their effects had not first been disinfected, and has ceased to occur after thorough and wholesale disinfection.<sup>2</sup>

It is also apparent, as far as railway traffic is concerned, that infection is carried less in the persons of travellers, than in their effects, seeing that though the spread occurs chiefly along the railway routes, the numbers of cases detected at inspection/

1. Vide Report of Indian Plague Commission, Chap. iii., Sec. VII. (3) pp. 111 and 112.
2. Op: Cit: Chap. III. Sec. VI. (7) (a) pp. 102-104.

tion posts have been very small in comparison with the numbers of persons travelling.

There can, therefore, be no doubt that this is a powerful factor in plague dissemination, especially as fabrics of a porous texture folded away in boxes or bags may retain the infection for a very considerable time on account of difficulty of access of desiccating factors. It is true that experimental attempts to isolate the virus from probably infected clothing has been attended with practically uniformly negative results; but this is in all probability due to its association with contaminating micro-organisms rendering its separation very difficult by any known method. Artificially introduced on to any fabric, and exposed to the ordinary atmospheric conditions obtaining in Bombay in the dry season, it dies within a week by the influence of/

of desiccation. At lower temperatures, however, even when exposed to desiccating factors, it is capable of surviving for considerable periods.

<sup>1</sup> Forster, Löffler, and Gladin recovered it from silk, wool, and cotton respectively after forty-five, fifty-six, and seventy-six days' exposure, under ordinary atmospheric conditions, to a temperature of from 18° to 25° C. The Indian Plague Commission<sup>2</sup> recovered it, under similar conditions after seventy days, and the German Plague Commission<sup>3</sup> after twenty-eight days.

It is very obvious, therefore, that measures for the arrest of travelling foci of infection in the persons of plague cases, and in infected clothing/

1. Centralblatt für Bakteriologie, Parasitenkunde und Infektionskrankheiten, Decr. 28, 1899, p. 722.
2. Report of Indian Plague Commission, Chap. VI., p. 364.
3. Report of German Plague Commission, p. 277.

ing are powerfully indicated as means for preventing the spread of plague by railway passengers.

Experience, however, has shown that it is not possible to organize and maintain such without the granting of concessions which might defeat their purpose; or to bring them to such a state of perfection that all possible means of evading them could be obviated, without practically closing the channels of daily communication and paralysing trade.

It is apt to be advanced, therefore, that, as they cannot be made absolute, their utility could never be expected to be commensurate with the expenditure and labour involved in organising and maintaining them. I would, however, strongly submit, as the result of personal experience extending over six years, that, if palliative measures be sufficiently rigorous to deter the infected, and probably/



bably infected, from travelling, and those from infected districts from carrying obviously contaminated baggage, they are of the greatest value in limiting the spread of plague; and I shall endeavour, in the course of this thesis to illustrate this fact from the published results of the measures as carried out in the Bombay Presidency under my supervision.

Before proceeding to do this, I shall give a brief description of what experience has indicated to be the most satisfactory method of organising such measures; and shall conclude the work by an enumeration of the principal features of the plague bacillus for facilitating recognition, and a summary of the leading points which aid in the diagnosis of doubtful cases among passengers detained under observation.

DESCRIPTION OF WHAT EXPERIENCE HAS PROVED TO BE THE  
MOST USEFUL MEASURES FOR LIMITING THE SPREAD OF  
PLAGUE BY RAILWAY TRAFFIC.

From the published results of railway medical inspection measures during the recent epidemics in India, it would appear that some hundreds of plague cases have been removed annually from trains. The significance of this is that as many hundreds of centres of infection have been prevented from becoming operative as such in healthy areas. Compared with the many hundreds of thousands who travel, however, this number is exceedingly small; and, indeed, plague has spread, and continues to spread, chiefly along the lines of railway communication. The presumption is, therefore, that such spread has occurred either by means of infected persons passing/

ing inspections posts, undetected, while only in the incubation stage; or that, while not being themselves infected, many persons have carried infection in their baggage.

As regards the first of these contingencies, the observation of a very large number of passengers detained as suspicious, and in whom undoubted symptoms of plague subsequently appeared, goes to demonstrate that the incubation stage is seldom unaccompanied by some such premonitory sign as pyrexia, giddiness, suffused conjunctivae, cerebral nausea, slow mental processes as indicated by disinclination to reply to questions, etc.; and, as practically all persons showing such signs have been detained as suspicious, the probabilities are that very few cases, if any, in this stage have escaped detection. It is, therefore, extremely unlikely/

likely that, with thorough inspection, dissemination occurs, to any extent, by persons in whose bodies the plague may be incubating.

It is much more probable that the infection is spread by persons carrying infected baggage; and, by disinfecting the effects of passengers carefully selected, on definite lines, as being probable carriers of infection, it may reasonably be expected that hundreds of thousands of foci would be stopped annually from becoming operative as such. The results of a system therefore, which did not include such disinfection could never be expected to be commensurate with the expenditure, while the inclusion of disinfection would not add materially to the cost after the initial cost on plant had been defrayed.

Experience has, moreover, demonstrated that it is only by combining disinfection of suspected baggage/



baggage with the removal of plague patients and doubtful cases from trains that an appreciably deterrent effect can be produced; and, as has been suggested above, it is necessary that for any degree of success, the measures should be sufficiently strict to act as a powerful deterrent against infected persons travelling, and those from infected districts carrying obviously contaminated baggage.

Any scheme therefore for measures directed against the spread of plague by Railway Traffic, should have as its aim the arrest of travelling foci of infection,

(a) By removing such from trains in the persons of plague cases.

(b) By rendering innocuous by disinfection, the effects of passengers selected, on definite lines, as being probable carriers of infection; and,

(c)/

(c) By rendering innocuous, by disinfection, railway carriages in which plague cases are detected, in order to afford protection to the travelling public.

(a) Removal of Travelling Foci of Infection in the Persons of Plague Cases.

To accomplish the removal of travelling foci of infection from trains, it is necessary that all persons travelling from infected places should be subjected at one or more points en route to a careful medical examination, all those exhibiting undoubted or suspicious symptoms being detained in plague or observation camps connected with the inspection posts.

When inspection posts form starting points for passengers from infected places, the local departures should be also thoroughly examined and prevented/  
ed/

ed from entraining if suffering from plague or exhibiting suspicious symptoms.

It is desirable that all passengers whose temperatures may be, in the least degree, supernormal should be subjected to a detailed and searching examination and detained under observation unless the inspecting officer is satisfied that the excess of temperature is not due to plague, in which case the passenger may be allowed to proceed with a credential which will procure for him exemption from restrictions at subsequent posts. For the selection of those whose temperatures should be taken, the temperature of the skin of the body and the state of the pulse at the primary examination afford ready guides. It is generally useful to subject to this test all travellers holding tickets from infected areas, and all those detained for disinfection, of their effects.

(b) Disinfection of Suspected Baggage.

The most rapid method of carrying out disinfection of suspected baggage is by subjecting it to saturated steam under pressure; but where this cannot be done, or time is of no particular importance, it can be effected by boiling the things in water or soaking them in chemical disinfectants and subsequently drying them in the sun, or, in wet weather, over fires.

Silk, woollen, or leather goods which would be injured by steaming, boiling, or chemicals, should be spread out in layers or hung up on lines and exposed thus for some hours to the direct rays of the sun.

In the selection of those whose effects should be disinfected, it is reasonable to consider those as probable carriers of infection who may be travelling/



ing with plague cases, and have been exposed to the same conditions as caused those to contract the disease; those from badly infected localities; and those whose baggage, on inspection, may appear to be sordid and obviously contaminated.

It may reasonably be objected that this measure could be largely evaded by persons dispatching their effects by goods trains; but this is a contingency which actual experience in India has demonstrated, never happens. In no cases do the natives voluntarily separate themselves from their baggage; only mendicants are ever observed to alight without bundles; and the only articles ordinarily dispatched by goods trains have been found to be articles of merchandise which would not in any case be disinfected. Even, however, if recourse were had to this procedure, it is better that as many foci as possible/

possible should be arrested, than that all should be allowed to pass because a few can escape, .as the measure aims less at limitation than absolute prevention.

At posts where there are arrangements for disinfection by subjection to steam, detention for the process should not occupy more than a few hours.

(c) Disinfection of Infected Railway Carriages.

When there is reason to believe that railway carriages from which plague cases have been removed have become infected, it is necessary to subject them to thorough disinfection as soon as possible in order to protect the travelling public.

The best agent for the purpose is the perchloride of mercury in a one in one thousand solution, which should, in order to ensure complete solution,

be/

be made up with hydrochloric acid or a soluble chloride.

To obviate the disadvantage of issuing the solution in bulk from central depots, a concentrated solution in acid of fixed strength should be issued in phials. When required for use, this solution should be mixed with water up to the required strength. To ensure that the proper strength is used, it is convenient to arrange that the quantities of the solution and water should be such as will quite fill the vessels of a standard capacity, the same number of vessels of each being poured into an empty bucket, or tub, until the required quantity of the diluted solution is obtained.

The solution should be poured freely over the floor, forcibly pumped into corners, crevices and other places which are difficult of access, and applied/

plied to the walls by mops or brushes. After free application it should be allowed to dry.

Cushion stuffing and covering should, if necessary, be destroyed and renewed.

PRINCIPLES UPON WHICH RAILWAY INSPECTION POSTS  
SHOULD BE SELECTED.

Inspection posts are desirable -- (1) between a province generally and the principal distributing centres of infection; (2) between infected districts as long as the epidemic is on the increase in these districts; and (3) between infected and free districts.

The utility of (2) - or the examination of passengers between infected districts - is likely to be questioned. It has, nevertheless, several important bearings. When contiguous districts are infected, and the epidemic is gaining ground therein, if/



if there were no means of limiting the free spread of plague by arresting as many travelling foci of infection as possible, the infected would travel freely and infect railway carriages, and thus, directly and indirectly, would constitute a severe source of danger to the travelling public; the epidemic would also become more widespread, and very many more units in the districts would become infected, entailing untold misery and a vast outlay of money in plague measures.

As regards the class of post necessary to meet the above requirements, there should be permanent posts at such stations as might be regarded as the railway gates of the principal distributing centre or centres of infection, with arrangements for steam-disinfection of the baggage of passengers. At these posts disinfection might be greatly relaxed/

ed, or stopped altogether, during the intervals between the annual or periodical exacerbations; but medical inspection would be necessary as long as plague continued in the centres, even in an endemic form.

By permanent posts those are not necessarily implied at which measures need always be in force, but such at which measures might be started at a day's notice if necessary, camps, hospitals, equipment, etc., being always ready for use.

Similar posts should be maintained at important junctions, especially those at which lines from several districts meet. In a widespread epidemic, measures at such posts could be employed in any one or more of several directions at the same time; and by having posts at junctions at which trains have to wait for railway purposes there would be no likelihood/

likelihood of interference with the companies' timetables.

Small temporary posts are desirable between infected and free districts, and between infected districts, while the epidemic is gaining ground therein. These should be arranged on the flying-column principle, tents being used for camps, hospitals, and quarters, and portable arrangements being provided for disinfection of baggage by boiling in water or soaking in disinfectant solutions.

It is important that staff trained for this particular branch of plague duty should, as far as possible, be retained for this duty only, being always kept available for it, even if, when not required for it at any particular time, employed elsewhere.

It should also be remembered that the value of measures directed against railway passengers would be/

be much enhanced, and their popularity assured to the travelling public and the railway companies, were the different local Governments concerned in limiting the spread to adopt an uniform system. Inspection posts should succeed one another on a definite plan arranged with due consideration to the interests of the different railway administrations and the public, and to the safety of the areas for which protection is sought; and not only the same rules, but also the same concessions and exemptions, should apply alike everywhere.

Bearing in mind the fact that rats may travel in goods trains, it is well to supplement the measures by a scheme for destroying these animals in goods vans and sheds, especially in those in which grain is carried or stored. The most satisfactory way of destroying them is by trapping and killing them/

them, and burning their bodies. A spring trap is generally found to be the most useful kind.



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11.

DEDUCTIONS AS TO THE RELATIVE VALUE OF THE DIFFERENT MEASURES ADOPTED IN THE BOMBAY PRESIDENCY FOR THE PREVENTION OF THE SPREAD OF PLAGUE BY RAILWAY TRAFFIC, DURING THE SIX YEARS ENDING 31st MAY 1902, FROM THE STATISTICAL RETURNS OF THE BOMBAY GOVERNMENT REFERRING TO THE COURSE OF PLAGUE DURING THAT PERIOD.

It is reasonable to suppose that the effects of measures which aim at the limitation of the spread of plague, by minimizing centres of infection, can best be judged by comparing the course of plague while such measures are in force with its course during other periods.

Appended to this thesis are two charts referring to the outbreaks in the Bombay Presidency during the six years ending 31st of December 1902.

The curves in that marked A will illustrate at

a/

a glance, the course of the disease during that period; the black curve represents the total number of plague cases according to months, and the red curve shows, similarly, the number of plague deaths.

The position of the dots between the horizontal lines gives, approximately, the numbers to which they relate between the limits marginally indicated on these lines.

The curves in Chart B represent an analysis of the black curve in Chart A, giving, separately the numbers of cases for Bombay City, and those for the different districts of the Presidency which are likely to be infected along the lines of Railway communication. The districts included are given on the title plate of the chart, opposite each being the particular colour referring to it in the chart. The black curve represents the Bombay outbreaks, and the coloured ones those in the above districts.

Entries/

Entries have, generally, only been made for those months in which the total number of cases in any particular district has exceeded one hundred.-

A glance at Chart B will illustrate that, for each of the first five of the six years under reference, the first of the two annual waves of infection indicated in Chart A represents, principally, the annual outbreak in Bombay City; and, the second, those in the districts.

It would appear that persons leaving Bombay, during the height of the annual epidemic, conveyed infection in their effects to different parts of the presidency, and that this gave rise to the series of outbreaks forming the second wave, either directly, by infecting human beings, or indirectly, by causing primary epizootics amongst rats.

During the year 1897 all measures were experimental; and, while no uniform scheme for limiting the spread by railway traffic was adopted throughout the/

the Presidency, several scattered inspection and disinfection posts were organized and maintained in various parts. There can be no doubt that these led to the arrest of large numbers of travelling foci of infection, as the second wave in that year was neither high, nor was the infection wide-spread.

In the following year(1898), in order, if possible, to obtain more absolute results, a system of detention camps was instituted at which passengers were detained for a fixed period, and the effects of all third class passengers thoroughly disinfected. The period of detention varied according to circumstances, the maximum being ten days ; all passengers from infected districts were detained excepting Europeans; Government, Railway or Native State Servants travelling on duty; and persons who held satisfactory credentials issued on certain definite lines as entitling them to exemption./



exemption. It may safely be said that this scheme was most successful in preventing the spread of plague by railway passengers; but it also had the effect of very considerably reducing the number of railway passengers; and, by closing the channels of communication, threatened to paralyse trade.

The people, moreover, evaded detention by travelling in carts or by foot, and, to a great extent, spread infection by so doing, judging from the height of the second wave in the year 1898.

The system, therefore, was not again attempted, but, in the following year, a scheme such as that sketched in the foregoing section was adopted. All passengers, and particularly those from infected districts, were subjected to a careful examination, the salient feature of which was the clinical thermometer test.

Baggage/



Baggage which, on inspection, appeared to require disinfection - by reason of the owners having been travelling with plague cases, or having been exposed to the same conditions which caused those to contract the disease, or having started from badly infected localities; or by reason of its being sordid and obviously contaminated - was thoroughly disinfected.

Only those suffering from plague, or exhibiting suspicious symptoms, or whose effects required disinfection were detained; and, in the case of the last, detention was, as a rule, limited to a few hours.

Combined, with the scheme, was a system whereby all persons arriving in healthy towns, or villages from infected areas were kept under careful surveillance for ten days.

Coming after the Detention camp system, these measures/

measures were popular both to the travelling public and the Railway Companies; and people began to make free use of the railways again. During the time they were in force an average of about 300,000 persons had their baggage disinfected, and over 500 cases were detected and removed from trains, annually.

From these results it might be assumed that hundreds of thousands of foci were arrested each year from becoming operative as such; and it was not only to this extent that the scheme was found to be beneficial, but the deterrent effect which it undoubtedly exerted against infected persons travelling and those from infected districts carrying obviously contaminated baggage, very considerably enhanced its value.

It will be seen from Chart A that though the second wave in 1899 threatened to be high, it subsided/

sided as rapidly as it appeared to be rising; and that, from Chart B, the infection which it represented was largely confined to the Poona district.

In 1900 when the system was well established and thoroughly understood, there was hardly any second wave at all; such as there was merely representing infection limited to a few districts near Bombay.

Towards the autumn of 1900, a general relaxation of the plague policy of Government throughout India led to considerable modification of this system. The principles upon which inspection posts were selected were changed; and the disinfection of suspected baggage was abolished.

It was considered to be, generally, necessary only to protect large uninfected areas from infected areas; and that it would suffice if such protection merely included the removal from trains of plague/

plague patients and doubtful cases.

There was thus nothing to prevent people from infected areas carrying infected clothing and other effects into healthy areas; nothing to deter those from infected districts carrying obviously contaminated baggage; nothing to check infected people from travelling freely between infected districts and depositing foci of infection in healthy parts of these districts; and not sufficient to deter the infected and probably infected from travelling, seeing that about 400 cases in a year were detected at the few posts which it was considered sufficient to maintain.

It will be seen from Chart A that in 1901 the second wave was considerably higher than it had ever been previously; and, from Chart B, that the infection which it referred to was very much more widespread/



spread and more severe; also that the worst infection was in districts remote from Bombay.

In 1902, not only was the second wave as high as in 1901, but Chart B demonstrated also that the infection was also very much more wide-spread; and that the first wave did not, as in previous years, principally represent infection in Bombay City, but that it referred as well to several badly infected districts.

While these statistics, per se, are not sufficient grounds for warranting the assumption of absolute causal connection between the modification of the measures and the increased severity and diffusion of the plague, I would strongly submit that they afford sufficient evidence to justify the conclusion that there is a considerable degree of causal connection.

It/



It is only reasonable to admit the existence of other factors; and, notably, the probability that plague, as it, from time to time, penetrates into fresh localities, leaves behind it foci of infection which restrictive measures are powerless to destroy. But it must be conceded that, were such factors the only ones operative, the diffusion would be very gradually effected, and there would be no very marked contrast between the statistical returns of succeeding years.

Reviewing the statistical returns to which the appended charts refer, the increased severity and diffusion are not only very marked but also very abrupt; and as the same experience has been recorded in the Punjab, and in other parts of India, the circumstances can scarcely be regarded as merely coincidental.

Assuming, therefore, the existence of an appreciable/

ciable degree of causal connection between the modification of the measures and the increasing virulence and diffusion of the plague, it cannot be denied that there is strong testimony in favour of the value of palliative measures provided that such be - on the one hand - sufficiently stringent to powerfully deter the infected and probably infected from travelling, and those from infected districts carrying obviously contaminated baggage; and sufficiently comprehensive to encompass the arrest of a large number of travelling foci of inspection; and - on the other hand - sufficiently elastic to prevent interference with trade; and sufficiently lenient to preclude the possibility of an array of popular feeling against them.

PRACTICAL ADVANTAGES WHICH ACCRUE BY LIMITING

PLAGUE DIFFUSION.

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The practical advantages which accrue by thus limiting the spread, and keeping the outbreaks within due bounds, cannot be over-estimated. When the extent of an epidemic is such as to out-run the administrative staff at the disposal of a Government, adequate suppressive measures become impossible; such as can be attempted, being practically valueless, give rise to widespread disaffection and a not-unnatural want of confidence on the part of the people who are required to submit to them; and it becomes impossible to control the movements of the inhabitants of infected districts, so that, not only are fresh foci of infection scattered broadcast in healthy places, but the danger of the exportation of infection to other countries is much enhanced, as is also the risk of infection to ordinary healthy travellers - either directly, by contact with plague stricken travellers or infected baggage; or, indirectly/

directly, by railway carriages, carts and other vehicles becoming infected.

On the other hand, when preventive measures obviously result in limiting the extent of an epidemic, and suppressive measures are attended with an appreciable degree of success, there is a greater chance of securing the confidence and co-operation of the public, and also of gradually educating them to protect themselves.

Apart from these, and many other self evident advantages, by endeavouring to render plague diffusion a slow process, there always exists the hope that, long before the disease would reach the dimensions which would be attained without adequate efforts to limit it, the means may be at hand for reducing, very effectually, the appalling mortality which now characterises it.

That there are reasonable grounds for justifying/  
ing/



ing such a hope exists in the fact that most encouraging results have been obtained by therapeutical experiments with the serum of immunized animals; and better results may be confidently expected by gradual improvements in the method of preparation and application of the serum; the line of progress, as pointed out by the Indian Plague Commission,<sup>1</sup> lying, not in the direction of applying the sera at present available - which lack antitoxic and antibacterial power - to the largest number of patients; but that of studying, in the case of animals who furnish the serum, the blood changes which are associated with the incorporation of the plague toxins, and with the elaboration of anti-dotal and bactericidal substances.

Professor Sir Thomas Fraser<sup>2</sup> considers that,  
in/

1. Report of Indian Plague Commission p. 320.
2. Ibid Appendix 11., p. 445.



in cases in which the infective agent is concentrated in buboes (preliminary to diffusion through the body), even sera such as have hitherto been employed, if brought directly into contact with it by injection near or into the substance of the buboes, would be likely to exert an energetic action, though inert if required to extend their action by diffusion through the body to the tissues and fluids.

It is manifest, however, that only sera with very strong anti-toxic and anti-bacterial properties can exert any influence after diffusion of the infective agent throughout the body, as, before exerting their antitoxic and anti-bacterial actions (which are strictly quantitative chemical combinations), they have to act, primarily, by dissociating the toxic and bacterial elements with which they are to combine from the body protoplasm, the energy necessary for this disruption being proportionately greater/

er as the elements to be dissociated are more virulent, or possess greater resistance to the destructive forces of the body.

Serum therapy, however, being the only rational treatment for a specific disease, and there being reasonable grounds for justifying the hope of important developments in its application to plague, there can be no doubt that a properly organized scheme for limiting plague diffusion would result in the eventual saving of many thousands of lives, and the consequent obviation of much of the unspeakable misery, and many of the too well known horrors, which carry in their train fanaticism, religious and caste intolerance and general retrogression.

A BRIEF DESCRIPTION OF THE PRINCIPAL FEATURES OF  
THE PLAGUE BACILLUS FOR FACILITATING RECOGNITION.

A. GENERAL CHARACTERS.

Obtained from the tissues or products of infected men and animals, the plague bacillus usually appears, under the microscope, as an ovoid body or cocco-bacillus, measuring from .8 mm. to .2 mm. in length, and from .8 mm. to .4 mm. in breadth, the breadth being generally less than half of the length (Diagram 1). Aggregation into twos gives rise to diplo-coccal forms (Diagram 2), and occasionally streptococcal forms are observed (Diagram 3).

When stained by ordinary basic dyes, it appears to be surrounded by a capsule, and this appearance is very much more marked when staining is effected by Pittfield's/

PLATE I.



1.



2.



3.



4.



Pittfield's method or other flagella-staining processes (Diagram 4). The shape is sometimes irregular (Diagram 5), especially in late post-mortem specimens, or in those from the blood and tissues of infected animals which possess, in a greater or lesser degree, either natural or acquired immunity. It is not motile, possesses no flagella, and its multiplication is independent of spore formation. Staining is readily effected by ordinary basic aniline dyes, the poles generally retaining the stain, and a vacuole being left centrally (Diagram 6), or laterally (Diagram 7). It is characteristic that it does not retain the stain when treated with Gram's process, unless, as pointed out by the Indian Plague Commission,<sup>1</sup> weakened (50 per cent.) spirit is/

1. 'Indian Plague Commission Report,' chap. III., p. 55.



PLATE II.



5.



6.



7.

is employed in lieu of absolute alcohol in the decolorization process.

Like other pathogenic organisms, it is capable of luxuriant growth and proliferation on artificial media, the most suitable being agar-agar, gelatine, or bouillon; but, unlike them, it exhibits this characteristic best at low temperatures, the optimum being between 85 and 95° F., though satisfactory growth occurs at much lower temperatures. The Austrian Plague Commission<sup>1</sup> were able to produce a certain amount of growth at a temperature as high as 107° F. Neutrality or alkalinity of the media are factors which favour its artificial cultivation. When cultivated it exhibits somewhat different microscopical appearances from those above described. These, moreover, vary according, not only/

1. 'Austrian Plague Commission Report,' part 11., C., p. 630.

only to the particular medium employed, but also as to whether the bacilli are from cultures recently derived from the animal organism, or from such as have been cultivated on artificial media for several successive generations.

B. MICROSCOPICAL APPEARANCES OF PLAGUE  
BACILLI FROM ARTIFICIAL CULTURES.

(a) AGAR-AGAR CULTURES.

Plague bacilli from agar cultures are generally isolated, and, if the result of several successive growths, show little or no vacuolation when stained. In cultures some days old, mixed with typical forms, are found involution forms, characteristic ones being more commonly found in recent cultures from animals than after several successive/

successive growths in the laboratory. Such may be elongated, spindle-shaped, dumb-bell-shaped, angular, irregular like amoebae, lemon or pear shaped, or branching (Diagrams 8., 9., 10., 11). They revert to typical forms when freshly cultivated on pure agar. Hankin<sup>1</sup> has demonstrated that exaggerated types of these involution forms can be produced by cultivation on agar containing from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  per cent. of common salt. This is of importance for diagnostic purposes, as the phenomenon appears to be peculiar to the plague bacillus, and not common to pathogenic micro-organisms. The irregular forms observed among bacilli taken direct from the animal organism may be of the same nature as involution forms, but are more probably the result of post-mortem/

1. Evidence before Indian Plague Commission, vide chap. lll., p. 59 of Report.



PLATE III.





mortem changes.

(b) GELATINE CULTURES.

The chief microscopical characteristic observed among bacilli from gelatine cultures is the appearance, among single and diplococcal forms, of filamentous forms, generally without transverse septa (Diagram 12). Klein<sup>1</sup> has demonstrated that some gelatine colonies produce only filamentous forms, and considers this to be of importance for diagnostic purposes.

(c) BOUILLON CULTURES.

Involution/

1. Vide chap. 111., p. 58, of 'Report of Indian Plague Commission.'

Involution forms are not seen among bacilli from bouillon cultures; but, though single and diplococcal forms are present, a streptococcal tendency exists, the chains seldom, however, containing more than six organisms (Diagram 13).

C.        MACROSCOPIC APPEARANCES OF ARTIFICIAL  
          PLAGUE CULTURES.

(a) AGAR-AGAR CULTURES.

The naked-eye appearance of plague cultivations on agar vary according to the age of the culture. The growth being rapid, colonies develop along the track of the needle within forty-eight hours. Some of these grow more rapidly and to a larger size than others. They present irregular margins, and are very sticky, especially in the case of recent cultures/

PLATE IV



12.



13.

cultures from animals. On dry agar, if the material has been spread evenly over the surface of the slant, colonies appear in the form of minute gray specks, with translucent margins, which give, when viewed by reflected light, a ground-glass appearance (Diagram 14.); these colonies increase in size, and at a later stage appear as a nucleus surrounded by concentric rings (Diagram 15.)

(b) GELATINE CULTURES.

Colonies on gelatine, resembling those on dry agar become visible to the naked eye on about the third day. The centres are opaque and yellowish, and the peripheries translucent, with irregularly crenate borders. They protrude from the surface of the medium, and, as in agar, differ in their rate of growth. Deep colonies take longer to develop/



PLATE V.



14.



15.

*(magnified four diameters.)*



develop than surface ones. In streak cultures the colonies, according to Klein,<sup>1</sup> somewhat resemble the growth in diphtheria, appearing in the form of a white band, increasing in thickness, and showing an irregularly knobbed margin. In stab cultures a thin white streak appears along the track of the needle, which does not increase in thickness, but the growth may spread as a film over the surface of the gelatine, and after some weeks filamentous outgrowths may occur from the stab, which, when present, are more abundant in the upper than the lower part.

(c) BOUILLON CULTURES.

The/

1. Vide The 'Bombay Plague,' part 11., chap. 111., p. 122.

The earliest naked-eye appearance of growth in a bouillon culture is generally that of a collection of floccular masses on the surface. These at first adhere to the sides of the containing vessel, but soon become detached. Haffkine<sup>1</sup> has demonstrated that, if ghee or oil be added to the bouillon, the colonies grow in the form of tapering stalactites from the drops of oil floating on the surface (Diagram 16.). If the vessel be slightly shaken, these colonies become detached, and fall to the bottom like flakes of snow (Diagram 17.), and on placing the vessel at rest fresh colonies grow in the same way from the drops of oil. This characteristic he considers to be absolutely diagnostic of plague. Hankin<sup>2</sup> has succeeded in obtaining stalactite growth with/

1. Evidence before Indian Plague Commission, vide chap. 111., p. 59 of Report.
2. Evidence before Indian Plague Commission, vide chap 111., pp. 59 and 60 of Report.

PLATE VI.



16.



17.



with other than plague bacilli, but the tapering colonies were very strong, and offered considerable resistance when the vessel was shaken.

Neither in agar nor in any solid medium does liquefaction occur, and, unless protected from circumstances which favour desiccation by such methods as keeping cultures in a moderately cool and dark place, and having rubber caps over the mouths of the containing vessels or tubes, the bacilli die out in a few days; but with these precautions they may survive for weeks or months, and in some cases for over a year.

A SUMMARY OF THE LEADING POINTS WHICH AID IN THE  
DIAGNOSIS OF DOUBTFUL CASES.

(a) CLINICAL DIAGNOSIS.

The recognition of typical cases exhibiting primary external buboes is never a matter of difficulty, excepting those mild cases (Pestis minor or Pestis ambulans) in which diagnosis is rendered difficult by the absence of those symptoms, the combination of some or all of which with painful buboes, and a history of a somewhat abrupt appearance, leaves no room for doubt, especially if plague be prevalent.

Such general symptoms include, mainly, a high temperature, a furred tongue with red tip and edges, **suffused** conjunctivae, a soft pulse, a listless appearance, hesitating or monosyllabic utterance and other/



other evidences of impairment of the mental processes.

During the course of an epidemic, however, the presumption is that the presence of tender and swollen glands which cannot be accounted for on specific, constitutional, or traumatic grounds is due to a mild invasion of plague; and it is of importance that this should be recognised, not because of any danger to those affected, but from the probability of their becoming centres of infection to others.

By no means, however, is the recognition so easy of the large group of cases in which external buboes are not an early manifestation, or are absent altogether. This group includes all cases exhibiting primary pulmonary phenomena, primary characteristics referable to the gastro-intestinal apparatus, or indications of the direct primary entrance of the microbe/

microbe into the blood-stream (the so-called septicaemic).

Beyond a strong suspicion that such are cases of plague, arising from the association of the particular phenomena with some of the general symptoms of plague, the consideration that plague is prevalent at the time, and the possibility of those affected having been particularly exposed to infection, a fairly presumptive conclusion can only be arrived at by a careful process of elimination or differential diagnosis, and a confirmatory one only by bacteriological tests.

(b) DIFFERENTIAL DIAGNOSIS

(1) Cases with Primary External Buboes.

Before the appearance of a bubo in any particular case, the initial rigor and rise of temperature are apt to be mistaken for ague; and when this is disproved/

disproved by the absence of a cold or sweating stage, and by the temperature remaining high, for remittent fever. The appearance of one or more buboes, however, and the rapid development of the general symptoms of plague, soon negative the latter suspicion and establish the diagnosis of plague.

If it be suspected, in the absence of marked general symptoms, that the buboes may be of venereal origin, such a suspicion would be disproved by the absence of local points of inoculation and of history of probable infection.

(2) Cases without Primary External Buboes.

(i) Cases exhibiting Primary Pulmonary Phenomena.-

The physical signs of such cases most frequently resemble those of lobular pneumonia; but the suddenness of the onset of the symptoms and their rapid development, the watery nature of the sputa, the/

the fact that blood when present in the sputa does not coagulate, the extreme prostration and the presence of other general signs of plague, all combine to render it extremely improbable that one so affected is merely suffering from pneumonia. In those cases, moreover, which are not rapidly fatal, the secondary involvement of the lymphatic system (characterized by the appearance of secondary external buboes) is sufficient evidence to warrant a positive diagnosis of plague. The physical signs, however, sometimes resemble those of lobar pneumonia on account of the coalescence of contiguous patches of affected lung into large areas of consolidation; but the rusty appearance of the sputa so characteristic of this form is never seen in plague pneumonia.

(ii) Cases in which the Primary Phenomena are referable to the Gastro-Intestinal Apparatus.-

Such/



Such cases have to be distinguished from cases of enteric fever, and they differ therefrom by the eruption being petechial; by the abdominal distension occurring early, and being associated with epigastric and lumbar pain, and with retching and vomiting; by the character of the stools (which are bilious, offensive, and occasionally mixed with liquid blood); and by the nature of the general symptoms.

(iii) Cases in which the Microbe has presumably primarily entered the Blood-stream.- These can be distinguished from cases of such affections as uraemic coma, which they often resemble, by the absence of history of kidney disease; acute alcoholism by the absence of smell indicating such, or by the history; epilepsy by the absence of the special signs of that disease, or by the history, etc. But there are conditions - such as some manifestations/

tations of cerebral apoplexy - which these cases closely simulate, and from which they cannot be distinguished, even by bacteriological tests, during life. In cases, however, of this nature, which are not rapidly fatal, the supervention of secondary buboes or pulmonary symptoms aids in establishing a diagnosis.

(c) BACTERIOLOGICAL DIAGNOSIS.

(1) Microscopical Examination of Blood and of the

Products of the Disease.- It is extremely rare to

find plague bacilli in the blood in large numbers,

except immediately before death in fatal cases.

Their absence therefrom in early stages of an attack,

and in cases which recover, must not, therefore, be

regarded as negating a diagnosis of plague.

They are generally present in large numbers in sputa of plague pneumonic cases at all stages of an/

an attack, and in the contents of buboes and plague blisters or boils until the supervention of suppuration, when, as has been seen, they probably get largely supplanted by the streptococci of pus, and partly or wholly disappear. While their presence, therefore, in the latter products may be regarded as conclusive evidence of plague, their absence does not necessarily justify negative conclusions.

(2) Diagnosis by Cultivation Methods.- These have a decided advantage over simple microscopical examination, in that the organisms, by becoming multiplied, are more easily detected. This advantage is of special value in the case of blood. It must be remembered, however, that the presence of contaminating micro-organisms may exert an inhibitory effect on the growth of the organisms; but, as pointed out by/

by the Indian Plague Commission,<sup>1</sup> while a positive result obtained by the employment of cultivation methods will be more conclusive than a positive result obtained by simple microscopical examination, a negative result (where contaminating micro-organisms appear in the culture) will, considered as evidence of the absence of plague bacilli, be less conclusive than a negative result obtained by simple microscopical examination.

The exaggerated involution forms demonstrated by Hankin<sup>2</sup> as being produced by cultivation on agar-agar containing from  $2\frac{1}{2}$  to  $3\frac{1}{2}$  per cent. of common salt would seem to be diagnostic of plague, the phenomenon not being common to pathogenic micro-organisms./

1. 'Report of Indian Plague Commission,' chap. iii., p. 63.
2. Evidence before 'Indian Plague Commission' vide chap. iii., p. 59 of Report.



organisms. Similarly, the stalactite form of growth demonstrated by Haffkine<sup>1</sup> as occurring by cultivation in bouillon to which oil or ghee has been added (Diagram 16), and the falling of these stalactite-like colonies on gentle agitation (Diagram 17), are absolutely peculiar to plague. Klein<sup>2</sup> also considers that the filamentous forms of the plague bacillus produced by cultivation in gelatine (Diagram 12) are of diagnostic value.

(3) Diagnosis by Inoculation Experiments.- Inoculation of an animal for confirming a diagnosis of plague may be considered to justify a positive conclusion, if, on the death of the inoculated animal, plague bacilli are found in its blood or spleen; but the method is not a reliable one as a test for isolating/

1. Ibid.

2. Vide "The Bombay Plague" Part ii., Chap. iii., p. 122.

isolating the plague bacillus when in company with contaminating microbes.

(4) Serum Diagnosis.— The fact that agglutinating substances are found in the blood of animals and men who have suffered from plague led the German Plague Commission to conduct a series of investigations to ascertain whether the phenomenon could be put to practical use as a means of diagnosis in doubtful cases. They concluded,<sup>1</sup> however, that the practical utility of the method is limited, for the double reason that definitely negative results are often obtained in the cases of persons convalescing from plague, and that the bacteria in a culture are, even in the absence of a specifically active serum, so massed together into clumps as to render it difficult to decide by microscopical examination whether agglutination/

1. 'Report of German Plague Commission,' p. 321.

tion has or has not been obtained by the serum.

Regarding this method the Indian Plague Commission express themselves as follows: 'We think that the difficulties and fallacies of the serum diagnosis of plague is rendered uncertain, not only by the fact that plague bacilli are normally agglomerated together into masses by the intermediary of their glutinous capsules, but also by the fact that these agglomerated masses, when they become detached, normally sink to the bottom of the containing vessel. It is thus, unless in cases of specially rapid sedimentation, practically impossible to be sure that a specific action is being exerted. Our personal experiences in the matter of the practical exploitation of the serum diagnosis of plague were extremely disappointing. We were quite unable to satisfy ourselves of the presence of specific agglutinating and sedimentary powers in the blood, either of plague convalescents/

convalescents or of persons who had been inoculated with Haffkine's plague vaccine. More than this, we were unable to satisfy ourselves as to the presence of any agglutinins in either of the two consignments of anti-plague sera which were kindly furnished by the authorities of the Pasteur Institute in Paris. In conformity with this, we are of opinion that no practical value attaches to the method of serum of diagnosis in the case of plague.<sup>1</sup>

1. 'Report of Indian Plague Commission,' chap. iii., p. 68.