

THE SPREAD OF PLAGUE IN INDIA.

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SINCE the publication of the Indian Plague Commission in 1901, with the exception of a short paper by Hankin (1905), comparatively little has been published in scientific journals dealing with the spread of plague in India from an epidemiological view-point. Not that this has been lost sight of in India, for there are many very valuable reports in existence in the archives of the various local Governments, containing most interesting observations made by officers of the Indian Medical Service who have dealt personally with the epidemics ; but as these reports are, in the nature of things, not available for reference by the public, it has been thought advisable and useful to compile a digest of them for publication.

Spread from man to man directly.

The contagious nature of plague was firmly believed in by the ancients and has remained the popular idea up to the present ; and yet it is recorded that many medical men—and among them the French physicians who visited plague-stricken Marseilles in 1720—were of a contrary opinion. From knowledge acquired in the recent epidemics of plague in India it would appear that there are good grounds for both opinions, for the contagiousness or otherwise of the disease depends largely on the type prevailing ; the “bubonic” type being very little contagious, while “pneumonic” plague is justly dreaded as one of the most virulent contagious maladies we have any acquaintance with.

At an early period in the prevalence of plague in Bombay city, it was remarked that almost none of the attendants on the plague-stricken in hospitals were attacked, and in the case of the few who did take the

disease, some evident cause was found, apart from the patients on whom they attended. Captain Thomson, I.M.S. (in Gatacre (1897), p. 51), who had charge of the large plague hospital at the Old Government House at Parel, reports that though 533 plague cases were treated there, there was no instance of the spread of plague from the patients to the nurses or attendants. Out of 140 attendants the only one who developed the disease was engaged in assisting at the post-mortem examinations, and probably thus acquired the contagion.

“In upwards of 240 instances the friends of the patients attended their sick, and in 20 instances scarcely ever left the bed-side, and in not a single case did the disease spread to the friends.” The same experience is reported from the Grant Road plague hospital by Dr McCabe Dallas (Gatacre, 1897, p. 94), who says that “except by pneumonic plague I do not think infection is spread by human intercourse”; for though 374 cases of plague were treated in hospital by him not one of the hospital staff was affected, and though there were “about 400 people—men, women, and children—who either visited their sick friends, or remained constantly at their bed-sides, together with the cases under observation, in not a single instance did any of these persons contract plague.”

The experience thus early acquired has been confirmed by observations in the Bombay city hospitals during 1898–1899 (Wilkins, 1899). Returns from 28 hospitals are available in which 9631 plague cases were treated. Among the attendants on these cases, who numbered some 764 persons, there were 36 cases, but of these only 12 appear to have been infected in the hospitals, apart from those noted below, where contagion from pneumonic cases was the probable cause. Twenty-four are accounted for as follows:—

Three lived in infected rooms outside the hospitals;

Ten lived together in quarters in which dead rats were found, attached to one of the hospitals, and the epidemic ceased on their removal to huts in the hospital compound;

Eight were in attendance on pneumonic cases, and all were affected within a period of six weeks in one hospital;

Two were inoculated by a cut and scratch respectively; and

One was a dhobi who washed unsterilised clothes.

When it is recollected that in all these hospitals the menial staff are uneducated, and for the most part very insanitary in their habits, the wonder is that so few cases occurred among them, and one is forced to agree with Captain Thomson when he says: “that one of the safest places during the epidemic is the ward of a sanitary plague hospital,

something more than mere contagion being necessary to develop the disease." If further evidence on this head were required, it might be found in the reports received from many hospitals of mothers suckling infants suffering from plague and not acquiring the disease themselves, and of the contrary condition where plague-stricken mothers have nourished infants without communicating the disease to them. (Gatacre, 1897, p. 52, and Collie, 1898.)

For direct communication from man to man we must look to the small percentage of cases of primary pneumonic plague, and those which developed pneumonia as a secondary complication. The prevalence of these several types doubtless varies in different epidemics, but the probable average incidence may be got from figures given by Col. Wilkins (1899, p. 158) for the hospitals of Bombay city for the year 1898-1899. There, out of a total of 9493 cases of plague, 1515, or 16%, had no buboes, and of these, 553 were cases of primary plague pneumonia. To these must be added 350 cases of secondary pneumonia, making a total of 903 cases which were probably dangerous from the point of view of direct man to man infection, a proportion of 9.5%.

A study of the pathology of such cases at once reveals the reason for their infectious nature, for the sputum in the pneumonic cases is often swarming with plague bacilli. In Bombay the first warning of the infectious nature of pneumonic cases was given by the attack and subsequent death of the European nurse who attended Major Manser, I.M.S., the president of the Bombay Plague Research Committee, whose case was the first where the diagnosis of this form of the disease was certainly established by the discovery of the plague bacillus in the sputum and its culture therefrom. Subsequent observation has fully confirmed this suspicion, and the invariable practice in hospitals now is to keep all such cases in a ward by themselves, and to warn the attendants to be particularly careful to avoid infection from them. That this is not always successful is proved by the occurrence of six cases among the staff of the Maratha Hospital, Bombay, between the 23rd of Sept. and 13th of Oct. 1898, all traceable to attendance on pneumonic cases, and five of the number due directly or indirectly to the illness of the resident medical officer, who himself died of this form of the disease.

Such cases of direct inoculation from the sick are common in this form of plague, one well-known instance being the infection of a European lady-nurse, Miss MacDougall, by sputum projected into her eye by a delirious patient.

To anyone acquainted with the careless and insanitary habits of the lower class native of India the spread of the disease around those afflicted with pneumonic plague must seem a matter of certainty and not of possibility merely. The patient is freely coughing up and scattering all round him a virulent culture of plague bacilli, and, regardless of all civilised customs, spitting on the floor on which he lies and the walls in his vicinity. His sympathising friends are ever ready to offer their open hands to receive the sputum and thereafter wipe them on the walls or doorposts, or their own garments. After witnessing scenes like these, which are of every-day occurrence, it does not require the exercise of the imaginative faculty to understand the spread of plague from man to man directly. When the fact is realised that these forms of septicaemic and pneumonic plague were not at first recognised as plague at all, the extreme danger arising from them, and the difficulty of controlling an epidemic when they prevail to any extent, is manifest.

Spread by means of animals.

The question of communicability of plague is greatly complicated by the fact that man is not the only living being affected by the disease. That rodents become affected in a peculiar way during epidemics of plague has been a common observation for centuries, but it was not till Kitasato (1894) and Yersin (1894) announced the discovery of the *Bacillus pestis* in rats and mice in Hongkong in 1894, that it became certain that the disease they suffered from was really plague. In India these observations were confirmed by Haffkine and Surveyor when plague broke out in Bombay in October, 1896, for they discovered that the plague-like bacilli found in the bodies of the sick rats produced the same involution forms when sown on dry alkaline agar as did the plague bacilli from human beings when similarly treated. The subsequent discovery by Haffkine (1897) of the formation of the "stalactite growth" by the plague bacillus when grown in bouillon proved the identity of the bacilli from the two sources.

Other animals which have been found to suffer from epidemic seizures of plague in India are the monkeys (Corthorn and Milne, 1899, and Hankin, 1898) (the *Langur* or black-faced monkey, *Semnopithicus entellus*; the bonnet monkey, *Macacus sinicus*; and the small brown monkey, *Macacus rhesus*); the common striped squirrel (*Sciurus palmarum*), so numerous in the verandahs and gardens of India, and the large bandicoot rat (*Nesocia bandicota*). Cats undoubtedly take

plague also, but have apparently a great power of resistance, and on this account are less liable to spread the infection than the animals mentioned above.

The evidence derived from Indian experience that rats spread plague infection is overwhelming, as the following extracts from the experience of plague officers will show.

A medical officer visited a village in the Punjab to investigate a reported outbreak, and on inspecting the corpse of a woman who had died the previous day, and whose body had been kept locked up all night, "to the horror of all it was found that the nose and part of one cheek had been gnawed away—presumably by rats." The investigation proved that the old woman had died from plague, and the body was burnt as soon as possible. But during the next few days every house in the block of buildings in which the corpse was found was infected. Brahmins, Jats and Telis were attacked (*i.e.* people belonging to three different castes) and numerous dead rats were found when the house was disinfected.

Clemow (1900) relates the following from his own experience in Calcutta:—"A native died early in the morning of 15th June, 1898. I saw the body at 7 a.m., four hours after death. The *post-mortem* signs and the history of the illness left no doubt that the man had died of plague, and this was further proved by the isolation of plague bacilli from the bubo (in the left groin) and from the liver. In examining the body I observed that one big toe had been partly eaten away, evidently by rats. In the godown where the body had lain three rats were discovered shortly afterwards, and dead and dying rats were seen on the adjoining premises during the next week or two. On June 30th—15 days after the occurrence of the first case—a European sickened with plague in the adjoining house. In this case, the patient stated that, two or three weeks before his illness, his dog brought a dead rat and put it on his bed; the patient had touched the rat in removing it from his bed. Seven days after this patient sickened, a Eurasian female living in a house four doors from where he lived, and three doors from the house of the original patient, was attacked with plague. It was ascertained that dead rats had been found in her garden, and that she was in the habit of gardening and of spending much time among the flowerbeds where the dead rats were found. Dead rats were also seen in the premises of the next house to hers. Thus in five out of six houses, in one street and all adjoining, a mortality among rats was observed, immediately subsequent to the incident above described—the con-

sumption by rats of the tissues of a human plague cadaver. Human cases of plague occurred in three of these houses (including the original case). There is scarcely room for doubt that the disease was spread by rats." Captain James, I.M.S. (1899, p. 96), relates the following striking instances of the spread of plague from one house to another, belonging as they did to separate castes. "At Khan Khanan, one of the first houses to be attacked by plague was that belonging to a Khatri named Bhagwana. Adjoining this house at the back, but having its entrance in another street, lived a Tarkhan or Sikh carpenter named Bhagwan Singh. These two families had nothing to do with each other. One day soon after the Khatri's house had been infected, Bhagwan Singh and his family noticed a rat coming out of a hole in the wall. This hole he afterwards discovered led into the Khatri's house. The family noticed that the rat took no notice of their presence, and that it was more or less *behosh* (unconscious) and after wandering about for a short time lay on its side and died." On the following day several of Bhagwan Singh's family were attacked by plague. From the description given it was at once recognised that the rat had died from plague, for when one of these creatures is thus attacked it behaves in a peculiar way, comes out into the open, and ceases to notice its natural enemies. It wanders about in an aimless manner, totters in its walk, looks dazed or mad, and ultimately falls on its side and dies, not in holes and corners as is usual, but wherever it may chance to be. It evidently suffers much from thirst, and is therefore found near wells, bathing platforms, or open drains.

In the same village another example occurred, in a block of buildings near the gateway. A Jat girl was the first victim, and the only entrance to her house was by the road leading to the main gate of the village. The next house to furnish a case was one opening off an alley inhabited by Ramdasis who had no dealing with the Jats; but the building was back to back with the former one. This second house touched by one corner a house belonging to the Chamars, a low caste the members of which had hitherto escaped. The day they were turned out into the camp however Indi, wife of Rura, was attacked. She must therefore have been infected in the village, and on search being made it was found that house was the next to the Ramdasi's house. "The Chamar's quarters had no direct communication with the Ramdasi's quarters, nor had the family attacked anything to do with the other two families."

A final instance from the Punjab may be quoted. In Ludhana

Jhikka, two families were attacked, one a Mohammadan, the other a Hindu Jat. The first case was in the person of Salamat, wife of Sain, of a Muhammadan family, who lived with their corelationists in a little courtyard just outside the village. To enter the Jat's quarters it was necessary to traverse tortuous lanes, leading apparently to the centre of the village. On mounting the roof of Narain Singh's house, where the next case occurred, it was however evident that the lanes had brought the investigator back towards the Muhammadan's quarters, for on looking down, Sain's house was seen below and separated from it only by a cow-shed. The houses were close together, yet there could have been no direct human intercourse. One of the medical officers, who worked in the Punjab villages through the whole of this epidemic (1897-98), says (Walton in James, 1899, p. 171), "the disease appears to have passed from one house to adjoining houses, influenced merely by the proximity of the houses, and scarcely at all by the convenience of human access from one to the other. Thus after the roofs of infected houses had been removed, standing on an adjacent house-top, one could trace an almost unbroken chain of infected houses stretching often through several distinct quarters of the village. On enquiring into the caste and other circumstances of the inhabitants, one often found that there could have been no common interests or communication between the owners of adjacent houses—one might be a Brahmin and his neighbour a Chamar¹—and to pass from one house to the next along the lanes of the village it was often necessary to make a wide detour, leaving the village by one gate and entering by another." All these examples and many others which might be given, almost irresistibly suggest the idea of spread by animals whose "runs" pass from one house to another irrespective of caste or other prejudice.

Several cases are known where infection was spread through a village in the absence of the human inhabitants; thus disposing of the argument that perhaps people communicate with each other across the flat-topped houses. The village of Mehlgahla was evacuated on the appearance of plague among the Chamars (James, 1899, p. 97). No dead rats were then noticed, nor did the rest of the village appear to be infected for none among the other castes had died. The village remained empty for twenty days, and was then disinfected. The villagers were allowed to help in this operation, and several of them were struck down with plague, and dead rats were found in numbers all

¹ The Brahmin is the highest caste among the Hindus, the Chamar one of the lowest.

over the village; and the opinion of those who saw them was that they had died of plague. "It is very difficult not to run to the conclusion that it was the rats which had spread the infection from the Chamars' quarters all over the village." The town of Banga (James, 1899, pp. 29 and 98), population 4727, was treated by partial evacuation of the various *Mohallas* (quarters) as they became infected. The evacuated portion was completely separated from the rest by temporary walls built across the approaches, and yet the disease seemed to slip past and attack fresh parts of the town. After a longer or shorter time the people living in the surrounding quarters began to see sick rats; and on bacteriological examination of them one was found to be infected with plague bacilli. Those people who were at once removed to camp escaped, those who remained were quickly attacked. No direct proof that man can get plague from having plague-infected rats in his house is yet forthcoming, but the reading of occurrences like the above and the two now to be related make this very probable. Dr Cayley (1899, p. 22), Deputy Health Officer, Bombay, wrote in May, 1899, "The only part of Bombay practically in which Europeans have suffered to any extent from plague has been Elphinstone Circle. This, in my opinion, is due to the fact that there are double floors to this building in which rats swarm. The space between the floor is foul. There were cases of plague in the house in question last year as well as this year. The same is likely to occur next year unless something is done. I have looked at several of the houses where plague has occurred. They are mostly clean, bright and airy. The double floors, with the facility they give for the breeding of rats is the chief point in which these houses differ from other European houses, and I am confident that this is the cause of these houses being infected with plague."

In the month of February, 1900, plague broke out in the Umerkhadi gaol in Bombay, 19 cases occurring. One of those attacked was Fatma, an inmate of the female ward. The occupants of this ward, which is an upstairs one, do not mingle with the male convicts, and the women attacked had been in the gaol for ten months. The previous cases had been among the males, and the question arose, How did the disease gain access to the female convict ward? A rat with all the usual symptoms of plague had been found in this ward two or three days before the seizure. Unfortunately this rat was not examined, but another one found in the gaol a short time afterwards was sent to the Plague Research Laboratory and proved, by culture from the spleen, to have plague bacilli in its body.

The finding of so many cases of plague in rooms under the tiles is also suggestive, for rats, especially *Mus rattus*, frequent the crannies among the tiles and rafters and are fond of building their nests there.

The handling of rats dead of plague seems attended with danger. A number of rats having been found in the warehouse of a Mr Wadia, in Bombay, he engaged twenty coolies to remove the bodies and clean the place. Out of these twelve were attacked with plague shortly after (Hankin, 1898, p. 722).

At Karachi a boy of 15 years was attacked with plague three days after playing with a dead rat. There had been no human case there for 14 days (Bainbridge, 1897).

Dr Louis Godinho, District Health Officer, Bombay, told me of a friend of his, Mr Saldanha, who scoffed at the warnings of his friends, and insisted on tossing up the body of a dead rat and catching it several times. He took plague two or three days afterwards and died.

Taking it as proved that rats are a means of scattering plague infection, it is not difficult to imagine how the germs may gain access to the bodies of men. The habits of the natives of India are such that their hands and bare feet are constantly brought in contact with the floors. They sleep and eat on the floors; on rising from the floor they use their hands placed on the floor to assist them, and they then when trimming their beards or moustaches or picking their noses, transfer particles of dust directly to the mouth or nostrils. When in the house shoes are discarded by all, and the cracks and fissures to be found on the feet of all barefooted races may furnish an easy means of entrance for the infection. Such are the arguments advanced by those who maintain that rats are the principal means of spreading infection in a village or town; it remains to be seen what part they play in introducing plague from neighbouring villages.

Here it is necessary to warn the reader that the common rat of India and the one found in its houses is not the brown Norway rat (*Mus decumanus*) now universal in England, but the so-called old black rat of England (*Mus rattus*) which is now rarely found in Britain.

Mus rattus by consorting for centuries with man has become almost a domestic animal.

The Norway rat, *Mus decumanus*, though certainly not indigenous in India, is found now in all large towns, and along the banks of the rivers and canals, having been introduced no doubt by ships (Aitken, 1899).

According to Aitken the Indian house rat is a most nimble climber

and when it enters a house always takes up its quarters in the roof. But the majority do not live in houses at all but in trees. In the monsoon they come into houses more than at other times for refuge from the rain. When the monsoon is over they go out again and lead a vagrant life, feeding on seeds and fruit and birds' eggs, and even on birds, which they catch sleeping. They climb trees and do much damage to young cocoanuts.

To an animal of such habits, an Indian village, with its thatched roofs to nestle in, and its stores of grain to feed on, must offer every attraction, and we need not be surprised to hear of nearly 200 being found dead in a single house, as mentioned in one case in the report by James on Plague in the Punjab.

It appears that rats freely roam from one part of a town to another, having no fixed abode, and at ordinary times keep out of sight; their presence being only known by the noise they make at night scampering in the ceilings, for they are shy animals. Concerning the occasional migration of rats from a building the following is of interest. Veterinary-Major Brodie Mills, Principal of the Bombay Veterinary College writes in a private letter dated March, 1900, "The matter is quite vivid to me now. About the end of September, 1896, one morning at 2 a.m. I was awakened by the noise of numerous rats running from under the eaves of the roof of my bungalow. I at once got up and found that they were leaving the place in a body. From that time I never saw a single rat or mouse in the house or compound, and to confirm the fact that none were present I frequently left food about and it was never touched." No connection between this evacuation of the house and plague can be traced, for no cases were reported from this place, which is seven miles from Bombay, for three months afterwards. Lieut.-Colonel Weir, I.M.S., Health Officer of Bombay, writes, in a private letter dated April, 1900, "I have seen them (rats) in 1898, on Bandra Hill, enter my house suddenly in large numbers and suddenly leave. They were in such numbers that in a single night on everything dung was seen. It took several days to sweep the dung away. I could not have believed it had I not seen it." Dr Louis Godhino, one of the District Medical Officers of Bombay, tells me that he himself saw three or four rats moving up a gully between houses in Khoja Street, and that the houses they went towards were those next attacked. On another occasion he saw five or six rats moving together to Dukar Gully across an open space towards Burrow's Lane, and several dead ones were also seen in the surface drains there. Shortly after this

the house in Burrow's Lane began to return cases of plague (Report of Municipal Commissioner for Bombay, 1898, p. 204). Lieut.-Colonel Weir (*ibid.* p. 143) says in one of his reports, "The death of rats is not the first phenomenon. Previous to this there is a migration of the animals." But it appears that he infers this from the appearance of rats in gardens and houses where they have not before been noticed, and has never himself seen or heard of anyone who has actually witnessed such a movement. He has seen dead rats, however, on the Bandra causeway, and on the roads leading to Malabar Hill just before the appearance of plague in these places. The conclusion from this evidence seems to be that rats when attacked by plague come out by day contrary to their usual habits, impelled by the fever-thirst to look for water; and that owing to this and their peculiar limping gait attention is directed to them. Probably they wander just as much when in health, but being shy animals escape observation. That they disappear from a village is undoubted, but whether this disappearance is due to flight to the fields around, as maintained by the people of Khan Khanan (James, 1899, p. 18), or to death is not apparent.

Spread of Infection by means of Clothes.

That plague may be communicated to men and animals by the clothes of the sick is a common belief, but one not easy to prove.

In India, as is natural, evidence is more plentiful and easier of examination. Major Collie, I.M.S. (1898), relates the following striking instance from his experience. "A man lost his wife from plague in Bombay, and ten days later he brought her clothing and ornaments to his house in a village near Harnai in the Ratnagiri Collectorate. In about a week dead rats were found in this man's house and neighbourhood, then one relative after another sickened and died from plague, and ultimately the man himself became the sixth victim. None of his relatives had been out of their village. Eventually this village and others suffered severely, and many lives were lost. No plague cases had occurred up to the direct infection."

Captain W. Ronaldson Clark, I.M.S. (James, 1899, p. 152), brings forward several instances in which conveyance of infection by clothes seems the most likely means of introduction in some villages in the Punjab. In a part of the village of Palewal quite separate from the infected portion lived an old bed-ridden Rajput woman, who used to send her grandson—who had been inoculated against plague—to the

Nathu's house to enquire daily as to the condition of the plague-stricken there. She got the plague and died, while her grandson, who was the only other inmate of the house, and who probably brought the disease to her on his clothes, escaped.

Parowal (James, 1899, p. 89), another village in the same district, was apparently infected as follows: Maiya, a Jat of Parowal, had a daughter married to a man in Bhajjal, where plague had broken out. The son-in-law fearing the destruction by disinfection of his wife's embroidered clothes sent them to Maiya, in whose village plague had not yet appeared. This was a common habit with the villagers in that part during that epidemic. When plague was first discovered in Parowal Maiya's house had already furnished two fatal cases, and his married daughter's embroidered clothes were found in the house.

In Kulewal (James, 1899, p. 91), a village of 300 inhabitants, the first case was in the person of Chande, wife of Dula Singh, lambardar of the village, who had broken through the police cordon of a neighbouring infected village, and brought away from it some money wrapped in a cloth which he kept in his house. His wife developed plague five or six days afterwards and died; Dula Singh himself was the next case, and he also died. As there was no sweeper in Kulewal, one Buti from Chinkoa used to come and work in Dula Singh's house. After the deaths of Chande and Dula Singh some of the deceased's clothing was given to Buti, who took them to his house in Chinkoa, where a few days after plague appeared in the next house, in the person of a Chamar having a good deal of intercourse with the sweepers. The next case was in the family of the sweeper himself.

Lieut. Walton, I.M.S. (James, 1899, pp. 68 and 171), reports the following incident, which had impressed upon his mind the idea that plague infection could be conveyed by clothes. The fact that plague existed in the village of Shikohpur had been successfully concealed by the inhabitants (numbering 517) for some time, and over 75 persons were attacked before the people could be moved out into camp. Contrary to the usual experience, the disease did not stop at once after evacuation, and not until all the clothes and property had been disinfected was the disease finally got rid of. The result was so immediate that Dr Walton came to the conclusion that the clothes had been the means of keeping the infection alive and active.

The Collector of Ahmednagar reports that in October, 1897, Rajapur (population 1532) was infected in the following way. The clothes of Marwari, who died of plague in Sirur, were presented by the

brother of the deceased to a family of Mahars, of whom five caught the infection and died (Condon, 1900).

An outbreak of plague among the coolies employed to unload the railway waggons used for removing the refuse of Calcutta is attributed by the Health Officer (Cook, 1900) to the collections of rags removed from the rubbish and stored in their huts. The rags were destroyed and the men put on oath to their goddess to desist from storing them in future, and the disease speedily disappeared.

In the report of the fifth season of plague in the Punjab (Wilkinson, 1904, *a*, p. 29) it is recorded, "That infection could be carried by clothes was however recognised by the people of Ambala district fairly soon, and in all towns the practice of burning the clothes of persons who died of plague was introduced and acquiesced in by sweepers who had previously suffered severely from taking the abandoned clothes of the dead." In Patiala State it was noticed that infection was also conveyed by clothing and bedding of persons who had died from plague, and this was so borne in upon the sweepers of Patiala that they refused to touch these articles, which often had to be burnt where they lay in consequence.

Again in the report for the following year (Wilkinson, 1904, *b*, p. 17) it is noticed that "several instances were observed where thieves who had stolen infected clothing and taken it away to their own villages died there of the disease." In Jullunder district "infection through contaminated clothing was clearly made out at Danduwal. Clothes were brought to a house in this village from Shahkot in the cold weather of 1901-02. In November, 1902, the clothes were taken out of the cupboard in which they had been lying. Rats died in the house shortly afterwards, and about five days after the first case among human beings occurred in this house."

The part played by men and rats respectively in the transference of infection to a distance.

To quote Aitken (1899) again: "The Indian house rat is not fond of crossing open country, where it would be at the mercy of any owl, cat, or mongoose that saw it. It trusts for safety to concealment and to its agility in climbing. In the Deccan it seems very unlikely that infection could ever be carried from village to village by rats unless the interval were very short. But in well-wooded country a rat might get over a considerable distance in the days that elapse between its infection and its death. And where its own legs would not take it, it might be

carried in carts and boats. The native craft in Bombay harbour swarm with rats, which pass from boat to boat, and from boats to the shore with wonderful facility." Captain James, I.M.S. (1899, p. 98), discusses this question in the light of experience gained in the villages of Jullunder and Hushiarpoor district of the Punjab, and the following is a condensed account of his arguments. No rats have been seen going from one village to another, nor have dead rats been found far from dwellings, both of which ought to have happened. So the idea gained ground that human agency was alone responsible for *introduction* into a village. But in the end of March, 1898, certain other matters came to light. Instead of occasional villages being attacked as before, many villages now became centres from which the disease spread to adjoining ones; as many as 23 villages in March and 29 in April being infected. The only change in surroundings was the increasing heat and the ripening of the corn. After April the disease ceased to spread. "The wide increase of the disease corresponded with the appearance of the ear in the corn and its decline with the closing of the granaries."

Chak Kalal was almost surrounded by plague-infected villages and as a precautionary measure the inhabitants were put into camp; for although no plague had appeared among them, rats were dying in a suspicious way. Eight days after the evacuation, the sky becoming overcast, and the people fearing rain, they went back to their houses for a few hours for shelter. Numerous dead rats were seen in the houses and one examined bacteriologically showed plague bacilli in its body. A few days after this transient visit to the village two attacks developed and a severe epidemic followed; 32 being attacked, with 19 deaths. There seems little doubt that these people got the disease from the rats which had begun to die ten days before them. How did the rats become infected? Either diseased rats must have come from the neighbouring village or else infected clothing started the epidemic among them. One Sunder Singh of Chak Kalal had indeed been to visit a sick friend, but as neither he nor any of his family ever developed the disease, the idea that he introduced infected clothing seems unlikely.

Again, the Muhammadan hamlet of Hamirowal was situated close to a village of Jats, with which it therefore had no intercourse. Yet rats died in Hamirowal on the day the inhabitants were turned out, and afterwards, though no deaths among human beings took place. In Punian and Lalpur also rats died before the first human case appeared, and the disease started with a rush among purdah women who could not have acquired it suddenly by human intercourse. From a consideration of these facts James concludes that for villages near one another there is

at times danger of rats introducing plague independently of human beings. In this opinion Major A. V. Anderson, I.M.S. (1899, p. 179), agrees, for in a report on plague in the Thana district he says, "towns and villages remote from an infected centre become infected by human intercourse, while contiguous places frequently become infected by rats carrying and propagating the disease."

From the recent Punjab report several instances might be cited. "From the facts recorded in certain reports of the migration of rats from infected or uninfected villages there can however be little doubt that these animals do occasionally introduce the infection of plague into previously uninfected villages" (Wilkinson, 1904, *a*, p. 10). Again, "in some instances it appears probable that rats actually convey the plague from an infected village to a neighbouring healthy one" (*ibid.* p. 47).

The Deputy Commissioner and the Plague Medical Officer of the Sialkot district believe that "the disease is also conveyed not only within infected places, but from infected to uninfected villages by plague-stricken rats" (*ibid.* p. 94).

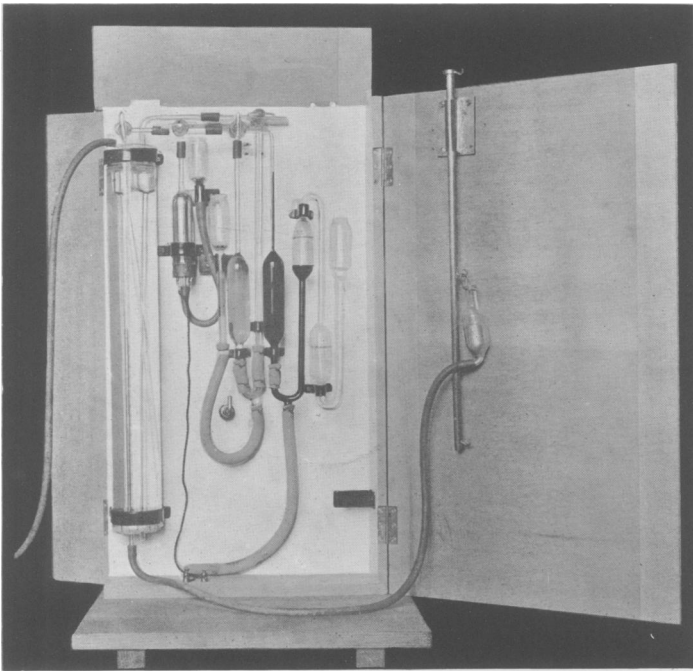
Mr Tollinton, Deputy Commissioner, writes (*ibid.* p. 95), "rats have been noticed immigrating from an infected to an uninfected village, in the immediate neighbourhood and dying on the way. Some must have survived; others were found dead on the outskirts of the village." "The Civil Surgeon (of Gujrawala) is of opinion from the fact that mortality among rats was frequently observed in villages before plague occurred among human beings that these animals also conveyed infection from one village to another in addition to distributing it throughout the infected villages" (*ibid.* p. 99). "From a study of the mode of introduction of plague infection in 89 villages in the Punjab, as recorded by various medical officers and embodied in Captain James' report, it appears that human beings were probably the agents in 77 instances, clothes possibly in 14, and rats perhaps in 4."

In the report on plague in the Punjab for 1902 the following information is given on what is regarded as "fairly definite" evidence. The mode of communication from one place to another was considered to be :

Human communication	in 88 instances.
Probably "	" 7 "
Clothes	" 25 "
Probably clothes	" 7 "
Recrudescence	" 1 instance.

The Government reviewer in commenting on these results says (Wilkinson, 1902, p. 15), "It is therefore clearly established now that plague is spread from infected to uninfected places almost entirely by personal communication on the part of persons who have resided in, or visited the infected places during the existence of plague there." In his summary of results derived from reports from the Punjab for the following season (1901-02) Major E. Wilkinson, I.M.S. (1904, *a*, p. 10), remarks: "All Officers, Civil and Medical, were convinced that plague is almost invariably conveyed from one place to another by human intercourse either directly by persons suffering from the disease, or indirectly in infected clothing or bedding or other personal effects." Rats are reported as dying "in many villages" before cases of plague appear in them, but as the earlier cases in an epidemic are largely concealed, this cannot be taken as implying introduction by rats. "From the fact recorded in certain reports of the migration of rats from infected to uninfected villages, there can, however, be little doubt that these animals do occasionally introduce the infection of plague into previously uninfected villages." In the Hoshiarpur district, "In most cases the infection of the villages was clearly traced to human agency, the virus being conveyed either in the bodies of plague patients or in personal effects. Fairly conclusive evidence to this effect was obtained by Dr Datta in the case of 66 villages. Once a village became infected, rats played a considerable part in disseminating the disease." "In some cases where a recrudescence of plague occurred it was noticed that rats died before any case among human beings." One village was apparently infected by having dead rats thrown into it by malicious neighbours (*ibid.* p. 40). Frequently rats have disappeared from infected villages, and returned after the subsidence of plague, when one observer notes that "they were all youngsters," evidently believing that all the adults had succumbed to the epidemic. Major Wilkinson believes that they do not invade fresh villages, but as a rule take to the fields because "firstly, nowhere has sudden increase of rats been noticed in any healthy village before its being infected; and secondly, rats when they find comfortable homes elsewhere are not likely to return to their native homes." The interval between the appearance of sick rats and plague cases in the house varied from 3 to 10 days.

In the report on Plague and Inoculation in the Punjab for 1902-03 (Wilkinson, 1904, *b*) the Government reviewer confirms his previous conclusions already quoted and adds:—"The disease is spread from village to village chiefly by the agency of human intercourse and



infected clothes. Within villages rats play a great part as agents in its spread, and they may spread it from one village to another in the immediate neighbourhood, but not to another at any distance." It is also noticed that plague is much more severe in country villages than in large towns, though the latter contain more rats. In the Ambala district it seemed that villages where rats had been cleared out the previous season escaped. In the Sialkot district, "of 63 villages in which special enquiries were made, in 47 the infection was traced to importation by human agency. In seven villages outbreaks were apparently a recrudescence of the previous epidemic, and in nine the inhabitants put it down to rats which were said to have died before any human beings. Dr Jones, the District Plague Medical Officer, remarks, however, that the more the latter class of cases were enquired into the more doubtful they became, as it was almost always found that there had been communication with infected places or that the place had been infected during the previous season." In Amritsar district, "of 391 villages in which enquiries were made, 284 reported mortality among rats prior to human beings developing the disease, 71 reported it to be subsequent to the outbreak among human beings, and 36 reported no rat mortality at all." But the District Plague Medical Officer remarks that the above had no scientific accuracy, as the first human case is often concealed or overlooked.

We may sum up the above evidence as follows:—As regards introduction into a new area remote from a focus of disease, it seems certain that human beings are the carriers of infection. In support of this may be quoted the dictum of the collector of Thaná, who says (Report of Sanitary Commissioner with the Government of India for 1897, 1899, p. 190) that "the plague adhered to the railway, and it almost confined itself to the area traversed by the local trains. Given accommodation for high-caste natives, and easy distance from Bombay, infection was everywhere a certainty." The man who introduces the infection is not necessarily the first victim, and sometimes does not even develop the disease. It appears to be more common for the disease to start among the rats of the house where the introducer lodges, and by this means to spread to other colonies of rats and human beings in the neighbourhood. Within towns and villages, however, the case is far otherwise, for here the universal testimony is that rats are the means of the dissemination of plague.

It also appears certain that in some instances villages hitherto free have become infected by the immigration of rats fleeing from plague-stricken places in the vicinity.

Recrudescence of plague year after year in the same locality.

In several of the instances given above reference has been made to recrudescence of plague in places where it had prevailed in the previous season. This has been a marked feature of the disease as observed in Bombay city and presidency, and likewise in the Punjab villages. Certain houses in a town, and even particular rooms in such houses, are well-known as furnishing plague victims year after year. As regards villages, the Punjab furnishes examples so certainly, that this year the chief Plague Medical Officer was able to indicate to the Plague Commission now working in India, many places where he was sure plague would reappear without re-infection. In the report on Plague in the Punjab for 1901-02 (Wilkinson, 1904, A) we find the following given by the Chief Plague Medical Officer as the accumulated experience of five epidemics:—"That the virus of plague does and can lie dormant during the hot weather months, and that it regains its activity with the approach of the cold weather, experience in the Punjab renders it almost impossible to doubt" (p. 11). The Deputy Commissioner of Jullunder district has no doubt as to recrudescence. He writes:—"In villages infected during the previous season plague generally makes its appearance first among the rats. Rats begin to die from 3 to 7 days before human beings are attacked" (p. 47). The Government reviewer of the report on Plague and Inoculation in Punjab for 1902-03 (Wilkinson, 1904, B) says, "in places which have once been infected recrudescence occurs without the reimportation of infection" (p. 3). These pronouncements of responsible authorities, representing as they do the accumulated experience of six epidemic years in the most grievously afflicted province in India, and agreeing with the universal belief of the common people, may be taken as fairly conclusive. It is not contended of course that recrudescence is inevitable, and that every house in which a plague case has occurred will show another in the following year, but it is certain that many houses, and even special rooms, do show fresh cases year after year whether they have been treated with disinfectants or not. Mr Bedford, I.C.S. (1905), who was placed on special duty by the Madras Government to report on plague administration in the Madras Presidency, has some excellent observations on this point. After some remarks on cases investigated by himself and others he says (p. 19), "The best case of recrudescence, however, that I find in my notes is that of the third epidemic at Karachi, described by Capt. Niblock, I.M.S., and also alluded to by Capt. Cornwall, I.M.S.

The sudden and simultaneous reinfection of distant quarters of a vast city is, under any hypothesis, a most extraordinary circumstance; but that all these various reinfections should be the result of so many simultaneous reimportations would seem to be an incredible coincidence. If this explanation be excluded, the causes of reinfection must be held to have been contained in the city itself, and this is essentially the doctrine of recrudescence. The second epidemic at Karachi impressed Captain Cornwall, Captain Niblock and Dr Elliot by the peculiar way in which the course of the infection followed the tracks of the course of the first epidemic, in so much that its course might have been predicted. The same feature in the case of the successive infections of Vellore city impressed two successive Municipal Chairmen (Capt. W. H. Tucker and the Rev. Mr Chamberlain) as well as the sub-Collector Mr Dutt. Capt. Standage noticed the same thing in Bangalore, and, in the conferences at Bellary and Hospet, I was informed that plague had broken out, year after year, in the same quarters in these two places." In his summing up Mr Bedford (p. 21) says, "in order to explain many of the facts in relation to successive epidemics, we are forced to admit the theory of recrudescence or to have recourse to conjectures which are supported by neither evidence nor probability or to invoke the aid of the miraculous and suppose that the reinfection of the same tracts year after year is mere coincidence."

These are powerful arguments, but no more can be said till further observation and experience are available.

The infectivity of houses, and the effect of bad ventilation, etc.

In India from the earliest times of which any record exists it appears to have been the habit to desert the infected towns or villages on the appearance of plague, and this practice continues to the present day in the endemic focus of Kumaon in the Himalayas. On the appearance of plague in Kumaon the people of their own accord evacuate the village; and erecting for themselves huts in the jungle, live there for some months till they consider it safe to return (Hutcheson, 1895). The people there are thoroughly convinced that the infection is one of locality, and that when they move they will leave it behind them. Recent experience proves that they are right, and the somewhat unscientific proceeding of running away from an infected spot is at present the most popular measure with plague

authorities ; for no method of " stamping out " the disease in India has yet been found. Many examples illustrative of the danger incurred by returning to infected houses might be cited, but only a few can be given here (Condon, 1900, p. 23).

Major Hyde Cates, Political Agent, Cutch, reports :—" The village of Luni was evacuated in December (1897), and in the end of January (1898) four persons of the village, with three relations, visited their house without permission. *All of them got plague, and four of them died.*" The Collector of Khandesh reports the case of a Bania, who returning to his house for his money, slept there one night, and was attacked by and succumbed to plague after his return to camp. A tailor, hearing that floors were to be dug up by the disinfectors and fearing for his money, secretly visited his house, slept there all night, and returned to camp only to fall a victim to plague two days later. A weaver, who had been for sometime resident in camp, suddenly developed plague, and it was found out that he had been in his house in town. So common did these occurrences become that when " dropping cases " took place in any camp suspicion was aroused as to the sufficiency of the guard over the village, and investigation generally led to revelations of secret visits to the houses by night.

Here is a case where a whole population returned too soon. The epidemic in Surat city (1897-98) was dying out, " and the end seemed within sight, when unexpectedly a cyclonic downfall of rain—most unusual at the season—occurred throughout the district on the 9th Feb. 1898. The immediate and necessary result was the return of all the persons camped outside the city and villages to their houses. The ill effects of this move were shown in the increased mortality of the next and following weeks."

Again, " Porbunder town was completely evacuated by the 25th May, 1898, after many cases of plague among the Kharwas had occurred. Between that date and 12th June, when the people were forced to return by the bursting of the monsoon on the previous day, only four cases had occurred." " This reoccupation was followed by a severe outbreak among the Kharwas, which spread so rapidly that after arrangements for watertight accommodation had been made complete evacuation was again insisted on." As a final example, may be given the case of Mandvi in Cutch, where the incidence of plague among the people remaining behind in the infected town is in striking contrast to that among those who evacuated the spot. From the following tabular statement (Condon, p. 26) it will be seen that the population *inside* the town

had more than double the number of cases of the seven times greater population *outside*.

Locality	Population	Period	Number of cases
Outside the town	35,000	4 months	206
Inside the town	5,000	Do.	421

Capt. Thomson, I.M.S. (1896), who early acquired large plague experience in the first epidemic in Bombay, as he had charge of the large plague hospital at the old Government House at Parel, was perhaps the first to call attention to the expediency of removing a plague-patient's family along with him to the hospital. He found that when this was done, no fresh case occurred in that family, whereas frequently when the family remained in their house more cases were brought to hospital from among the members. In six instances where the family remained two, three, four, five or more cases were subsequently brought for treatment; whereas in ten families where all the members accompanied the patient to Parel hospital no more plague cases appeared. Similar instances could without difficulty be brought forward, and the evidence all points one way, namely, that the infection is in the house or locality. The difficulty is to decide in what part. Yersin announced that he had found a bacillus, morphologically identical with that of plague, in the earth of a hut where a plague case had died; but Kitasato failed, though he examined the same floor. Hankin (Condon, 1900, p. 110), Haydon and Gibson (1898), Leumann, Liston (Condon, 1900, p. 124), and others have repeatedly examined soil without being able to find the plague bacillus. "Bacilli closely resembling it both microscopically and in their growth were found, but did not stand the final test. Rats inoculated with polluted soil generally died, but not of plague." Ransome, working with Gibson in the Plague Research Laboratory, once, and Leumann (1898) three times out of 25 examinations, isolated *bacillus pestis* from the floor, but they both attributed this to recent contamination from pneumonic sputum. Okada (1899) tried, by inoculating mice with washings of dust from infected rooms, to separate the plague bacillus from the countless rival organisms existing in such material, but failed. With soil from the surface of earthen floors, or from "below the floors" of rooms lately occupied by plague patients, he was successful in a certain number of cases. The number of mice inoculated in these experiments was 57, and the samples of soil used came from 26 different sites. Of these mice, 14 died of plague, the bacilli being found in their tissues; eight died of tetanus; three from malignant oedema;

six from some other cause, and 24 remaining healthy. He concludes that if the soil is rich in organic matter, possesses a certain amount of moisture, is protected from light, and not well ventilated, the bacillus of plague may retain its vitality for 11 days. That only 14 out of 57 experimental inoculations should have proved successful seems to point to the likelihood of contamination of particular spots on the floor only and to the absence of general diffused infection of the soil there. Gibson, in a series of experiments carried out in the Plague Research Laboratory, proved that rats injected with an emulsion of soil to which a minute quantity of the plague bacilli had been added, almost invariably died of plague, but that if soil from an infected locality alone were used they died of some other disease. It is probable then, in cases where success has been attained by this method, that the plague bacilli had been derived from pneumonic sputum or some similar recent contamination not yet thoroughly dried. Thus though the presumption seems natural that plague bacilli exist in the soil, yet, owing perhaps to defective technique, actual proof is still wanting. Recent experiments conducted at the Plague Research Laboratory, with artificially infected floor-soil, seem to show that plague bacilli rapidly perish in the presence of saprophytic organisms, and have completely disappeared after four days.

The question of the effect of want of ventilation, overcrowding, and dampness of houses has been much discussed. Those who, like Major Thompson (1897), say that plague is a "want-of-fresh-air" disease, point to the exemption from attack of such wandering tribes as the Byragis, who when asked why they were free from the disease answer, "We will not hang ourselves by living in dark holes of houses"; to the sailors and passengers on ships, among whom so few attacks take place; and to instances of such classes as the clean Brahmans who, living in close ill-ventilated houses, furnish a large proportion of plague cases.

On the other hand those who consider that something more than this want of fresh air is required to favour the occurrence of plague cases find no difficulty in discovering instances of good houses being badly attacked. In the Report of the Municipal Commissioner on Plague in Bombay, 1899, p. 21, we find the following instances. One of the district officers working in Bombay during the plague season of 1898-99 says, "When the disease attacked houses it seemed to attack all alike—badly-ventilated, dark, overcrowded chawls (flats) in which poor Ghattis live, as well as the large airy buildings of the richer merchants." Another says, in describing a virulent outbreak in the fort, "The houses

were of good quality—the rooms large and airy—while the majority of the occupants were away in camps.” Again, “Boregamker in Girgaum, inhabited by Brahmins—an exceptionally clean race—had a good deal of plague. The chawl is clean and well ventilated.” In the pages of the same report instances may be found of the opposite condition: “A very noticeable feature with reference to this locality (New Hanuman Lane) is that, though plague raged in the most virulent form all round it, a small area known as Angria’s Wadi remained perfectly immune until the month of January, notwithstanding the fact that it is most insanitary and thickly populated by a caste known as Karwas and the houses in it are dark, low, damp and densely packed.”

Surgeon-General Bainbridge (1897), discussing these points with reference to the first outbreak in Karachi, says: “It did not seem as if density of population and a marked absence of sanitation were the sole factors in favouring local outbreaks. Of such, several occurred among the residents of buildings which were well constructed in dry situations, and not closely packed. The occupants of upper stories had no immunity from attack. It was in fact made clear, that among people of uncleanly habits, and living as the humbler classes of natives usually do, a good house, and fairly clean surroundings with an absence of house privies, gave no guarantee of protection.”

That dampness in a house should render it unhealthy is in accordance with experience, but that it specially predisposes to, or is a cause of, plague has not been proved. A district plague officer remarks: “Dampness appears to have very little effect in determining the occurrence of plague. Out of 50 cases removed from one street only 11 occurred in rooms near water-taps.” But the Health Officer of Bombay holds a contrary opinion. In 1897 he caused all the water connections to be cut off inside houses in Kamathipura, in the hope of benefiting the conditions of the people as regards plague incidence. Little effect seems to have been produced, for the death-rate per thousand of population in 1897–98 was 21·19, whereas in the following year it had increased to 34·41. With a few exceptions (210 out of 1704 connections being restored) this condition of things was maintained in 1898–99, and the Health Officer remarks (Rep. of Health Officer, Bombay, 1898–99), “I believe the measure has had the effect of diminishing the cases, for it has to be remembered that the houses in which water connections have been cut off were all most insanitary,” evidently inferring that the increase of plague would have been even greater had the water-pipes been allowed to remain in the houses.

Spread by means of grain.

In the beginning of the present outbreak of plague in India suspicion fell upon the grain stored in the great export warehouses near the Bombay docks. That there is reason to believe that infection did emanate from these grain stores will be seen further on, but experience proves that it was not the grain in them, nor the bags used for storing it, that was at fault. Had the grain been in fault there should have appeared a sudden widespread epidemic such as is seen, for instance, when a water supply becomes infected with cholera, and the disease should have attacked the grain-dealers, but we know that this was not the case. Mr Hankin (Condon, 1900, p. 111) has carried out a large number of experiments with different sorts of grain and other articles of export, artificially infected with plague microbes. By injecting at stated intervals, emulsions, prepared from these samples he found that the mice employed for the experiments were not affected after the infected grain had been kept for 4-6 days. He points out that grain as it becomes rotten develops certain fatty acids and that these are destructive to the plague microbe, which dies out within 24 hours in these circumstances. He also examined a large number of specimens of grain from granaries, from sweepings of infected dwellings, and from rat-holes without in any case finding the plague bacillus. These results are compatible with practical experience, for no example pointing to the propagation of plague by means of grain is forthcoming. The following related by the Collector of Nasik (Condon, 1900, p. 24) is instructive. Trimbak in the Nasik district had been evacuated for some time. For a fortnight no cases of plague occurred; then two servants of the Trimbakeshwar temple surreptitiously entered a granary there and brought grain to the camp. Two or three days after this these men contracted the disease, and though others had also eaten of the grain only those who entered the granary suffered. This, the Collector says, appears to show that it was the building, not the grain, that was infected. In the Government Review of the report on Plague in the Punjab for 1900-01 we read, "In connection with the question of the spread of plague in articles of merchandise, and with reference to what is said by the Indian Plague Commission in paragraph 301 of their report, it seems worth while to note that Baniyas or traders have only in a few instances provided the first cases of plague in villages newly infected in the Punjab. Infected merchandise has clearly had no

part in spreading the plague from place to place in the province" (p. 14).

In the report for the following year it appears that, "No undoubted instances of the conveyance of infection in grain or merchandise were recorded during the year" (p. 11).

Again, in the report for 1902-03 it is said, "There is still no good reason to believe that grain and articles of food and merchandise are carriers of infection" (p. 3).

We may safely conclude therefore that grain cannot be incriminated.

Spread by Air.

From a careful study of all the available reports on epidemics of plague in India one fails to find any evidence pointing to the air being in any way dangerous in this disease. This conclusion is also in accordance with facts found out in the laboratory, for it is certain that infection is much more likely to cling to solid objects than to be carried about in the air. The members of the German Plague Commission (1899, p. 281) who visited Bombay report that, "The bacilli are very little resistant to external influences, *e.g.* drying, disinfectants, sunlight, and ordinary water; and as no spores are found their propagation through the dust of the air, especially in tropical climates, where they are quickly killed by sunlight and drying, certainly does not usually occur; only organisms which can resist drying being capable of dissemination by the atmosphere."

At the same time numerous cases of attack among those engaged in the disinfection of houses seem to show that *dust* brushed up from the floors and walls of a dwelling in which plague cases have occurred is dangerous. This is easily understood when the primitive habits of the lower-class native of India are considered, involving as they necessarily do the pollution of the floors and walls with sputum, nasal secretion and so on. The trained gangs of disinfectors do not however suffer so much as others, for they are carefully taught to soak walls, floors and furniture with disinfectant solution before beginning to clear out the rooms, so as to avoid raising a dust. When disinfection is performed by the inhabitants themselves, however, they do not use this precaution and many of them are attacked by plague. An instructive example of this may be found at p. 98 of Captain James' report on plague in the Punjab (James, 1899), where owing to the amount of work to be got through and the lack of trained labour the villagers were allowed to do a great

part of the disinfecting of houses themselves. It was found that each time a new quarter was commenced some of the people working at it were attacked by plague. The trained workmen being carefully looked after did not suffer.

Spread by Water.

That plague is a "water-borne" disease the Indian outbreaks furnish no evidence. Bombay city has an abundant supply of good pipe-water, and no evidence implicating this water has been brought forward by any of the numerous medical men who have watched the epidemics for the last four years. From careful laboratory experiments made by Hankin, as member of the Bombay Bubonic Plague Research Committee appointed by Government to investigate this and similar problems, it was found that the *Bacillus pestis* died out within five days or less in Bombay tap-water, and that therefore there was no likelihood that plague would attack whole communities at once, as cholera does, but that it spreads by slow degrees from a central starting-point. The members of this committee by their united labours were able to determine amongst others the above points in regard to spread by grain, etc., and on their arrival to inform the members of the various Scientific Missions sent to India by the German, Austrian, Russian, and other Governments, on these practical questions. The members of the German Commission fully confirm these views after many elaborate experiments (1899, p. 354).

The observation by Hankin and Leumann of the discovery of the plague microbe in brackish water at Sewri in Bombay would appear to require confirmation, for the cultural characteristics in bouillon noted by him differ from those produced by this organism (Hankin, 1897).

The rôle of Insects in the spread of Plague.

Yersin (1894) noticed a large number of dead flies in his laboratory in Hong Kong, and on examining one and finding in its intestines bacilli capable on inoculation into a guinea-pig of causing its death from plague, came to the conclusion that the flies had died of plague. Nuttall (1897 and 1899) made numerous experiments with flies (*Musca domestica*, in Germany) fed on the organs of animals dead from plague, and found that their faeces contained virulent plague bacilli for 48 hours or longer after such a meal, though in the interval they had been fed on sterile food. At a temperature of 12° to 14° C. (54° to 57° F.) all the flies were alive at the end of eight days. At temperatures from 23° to

28° C. (73° to 82° F.) the flies infected nearly all died within three days, but this does not imply that they died of plague, although he states that his control flies, in the majority of instances, especially at lower temperatures, outlived those fed on plague organs. Dr Nuttall's observations coincide with experiments made by the writer in Bombay, where flies kept in a tube containing a culture of plague bacilli, as also some control flies kept in a sterile agar tube, and in a bottle with sugar and water, almost all died within two days. Some of the control flies were dead before the ones in the plague culture tubes, and it therefore does not appear that the devouring of plague culture hastens their death. Doubtless, however, flies are able to play the part of the passive carriers of the disease germs from one place to another. Articles of food and drink might be contaminated in this way, as happens sometimes in the case of cholera, during epidemics in India (Macrae, 1894), but the probability of plague being thus diffused seems remote.

Hankin (1897, p. 437) made numerous experiments with ants (*Monomorium vastator*) in Bombay, and found that, when fed on rats dead of plague, their faeces contained virulent bacilli for a short time only, and that they carry away small pieces of the rats' bodies, but he came to the conclusion that "these insects cannot be regarded as important agents for the spread of the disease."

Blood-sucking insects, however, deserve more attention, as they may be capable of taking an *active* part in the propagation of plague. There is no evidence to show that the plague bacillus undergoes any kind of developmental change in the bodies of insects, such as is described in the case of the parasite of malaria, to fit it for injection through the proboscis of the blood-sucking insect. If these insects do carry the infection of plague it must therefore be by means of bacilli adhering to the outside of the lancets of the insect, or to its feet. Bugs and fleas have particularly been suspected, mosquitoes being acquitted on the ground that attendants in hospitals are bitten by them, equally with the patients, and yet escape infection in a marked degree. The same argument might equally apply to bugs and fleas parasitic on human beings, for they swarm in all native houses and hospitals, and do not omit to bite the hospital doctors and attendants, or those engaged in house to house inspection in infected localities. Hankin reports that he found plague bacilli in bugs from a plague hospital, and Ogata (1897) and Simond (1898) in the bodies of fleas taken from plague rats. Nuttall (1899) reports that experiments made by him on animals with plague, anthrax, mouse septicaemia and chicken cholera, all gave

negative results. In a large number of experiments made by allowing these insects to bite animals dying of the diseases named and then, immediately afterwards, transferring them to healthy animals; not a single case of infection occurred. Though the dejecta of bugs contained virulent bacilli after 24 hours they did not do so later. In fact it was shown that both fleas and bugs digest various pathogenic bacteria which they have taken up with the blood of diseased animals. "That a bug or flea filled with the blood of a patient containing plague bacilli may serve as a passive carrier of the germs may be safely concluded from my experiments with these and other germs, which were seen to remain alive and virulent in the bodies of those insects for 24 hours or longer, when they are kept at low temperatures. If such an insect were crushed and the skin scratched by nails soiled with the blood it contained infection might readily occur. In warm weather the insects are physiologically more active, and consequently digest the micro-organisms more rapidly." The results of these experiments of Nuttall are opposed to Simond's (1898) conclusions founded on trials made at Karachi. A rat dying from plague was placed in a wide-mouthed glass bottle, and twenty fleas from a cat were added to those already on it. A young rat, in an iron box grated on one side, was then lowered into the bottle, the two rats being thus separated though contained in the same glass receptacle. The young caged rat died of plague five days afterwards. Three similar experiments with a mouse, and two adult rats, were subsequently made by Simond, the mouse succumbing to plague, the rats remaining free. He, moreover, never succeeded in infecting a mouse or rat by placing it in contact with artificially infected animals in his laboratory when they were freed from fleas beforehand. Maitland Gibson (unpublished), working in Karachi about the same time, likewise failed to infect rats by keeping sick ones among the healthy, though neither were intentionally freed from fleas. That rats might be infected from rats by exchange of fleas seemed possible, but that the rat flea should have anything to do with the transference of plague from rats to men seemed highly improbable for rat fleas do not naturally feed on man. This was pointed out by Prof. Galli-Valerio (1900) of Lausanne, who criticised Simond's experiments from this standpoint. He declared that he could not persuade rat fleas to attack him, and that when removed from their natural host they do not bite. Netter agrees with Simond in thinking that the infection of plague may be conveyed by fleas from rat to rat and from rat to man, but believes that this mode of spreading is most common

from man to man. He says, "We believe that, as a general rule, parasitic insects belong especially to one species of animal. We have found in the case of laboratory mice—as M. Simond for rats—that when ill they are covered with fleas, which fly on all sides when one makes a *post mortem* on these animals; whereas in hospital consultations their relatives have not this discretion."

That the species of flea which infects rats in India, Australia, and Marseilles will readily attack man if hungry will be seen below.

Tidswell (1900) confirmed Simond's observations that virulent plague bacilli may be contained in the stomachs of fleas taken from plague-infected rats, but he failed to successfully repeat Simond's experiments indicating that infection could be carried from a sick to a healthy rat by means of fleas.

Kolle (1901) undertook a series of experiments to try and convey infection from rat to rat with the help of fleas. The results were entirely negative.

Zirolia (1902) pointed out that in some cases after fleas have sucked blood containing *bacillus pestis* these multiply in the stomach, and that they retain their original virulence for seven or eight days, during which time they may be passed in the faeces.

In the same year Gauthier and Raybaud (1902) performed experiments in Marseilles on the transmission of plague from rat to rat by means of fleas. The experiments were undertaken to test Simond's theory of the share taken by the parasites in the spread of plague.

In five cases they succeeded in transmitting plague by this means, under conditions which do not seem open to objection. The majority of the fleas used were of the species *Ceratophylus fasciatus* and most of the fleas they used bit man readily.

Later, Tidswell (1903) published the results of a study of the ectoparasites of the rat in Sydney, and found that the majority of fleas caught on rats belonged to the species *P. pallidus*, which bit man readily enough when hungry. Further attempts to experimentally transmit plague by fleas were negative.

Captain W. Glen Liston, I.M.S., one of the staff of the Plague Research Laboratory in Bombay, has during the last three years made a careful study of the distribution and habits of different species of rats in India and of the ectoparasites which infest them. A short account of his observations formed the subject of a paper delivered before the Bombay Natural History Society in Nov. 1904.

In this paper will also be found a large amount of circumstantial evidence in favour of the idea that plague may be transmitted by fleas.

Liston also found that the plague bacillus is capable of multiplication in the stomach of the rat flea.

According to Liston the commonest flea found upon rats in India is *Pulex cheopis* (Rothschild), which is the same as Tidwell's *P. pallidus*. Liston found that this flea attacked man in the absence of its proper host.

Among other instances given by him the following may be quoted (p. 13). "About the 6th or 7th of April (1904), rats began to die in large numbers in the chawl (tenement) in which this house was situated. Suddenly the deaths among rats ceased, and on April 11th the people became troubled with fleas. The fleas were so numerous that they had to quit their rooms and sleep out in the verandah. While living in the verandah on April 17th one of the inhabitants of the particular room in which the fleas were taken became infected with plague. Another case occurred on the same day in a room adjoining. This room was separated from the aforesaid room by a partition 6½ feet high. On the same day the information about this chawl came to Mr Lord. He succeeded in getting the people who inhabited the room where the above case occurred to collect some of the fleas from their persons which they said troubled them and he sent the collection to me on April 20th. An examination of the collection of 30 fleas caught on man under the circumstances above recorded, showed that no less than 14 were rat fleas (*Pulex cheopis*).

On previous occasions, of 246 fleas which were caught on man under normal conditions, I had only found one rat flea."

Anyone reading the various incidents recorded in the previous parts of this paper—all be it remembered collected before the flea theory was looked upon with any favour—will be able to judge how curiously most of them can be reconciled with the view that this insect plays an important part in conveying infection from rat to man in India.

"This hypothesis is consistent with the common phenomenon,

(1) plague among rats with many deaths,

(2) a lull,

(3) then plague among men" (p. 13).

It serves to explain the infectivity of clothes so often noticed. It is probably the fleas in the clothes that are the danger, not the clothes themselves.

It also serves to explain why there were as many buboes in the groin in the booted Australians as among the barefooted Indians of Bombay, for the legs are the places most often bitten by fleas. If the plague infection was derived from the soil the latter class of person ought to develop more groin buboes than the former, but this is not so. The fact that fleas are not as a rule to be found during the day, but only in the dark, serves to explain the danger of spending the night in a plague-infected house, and the clinging of the infection to the dark, dirty, overcrowded dwellings where vermin abound.

Should, as I believe, the idea that plague is disseminated in India principally through rats and that its spread to man is occasioned by the agency of fleas prove true, it is certain that sanitarians will have to alter their modes of dealing with plague, for if the infection does not reside in the floors of houses, what is the use of pouring disinfectant on them? Other methods directed to the separation of the lives of men and rats must be substituted.

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