RATS, FLEAS, AND PLAGUE

A THESIS FOR THE DEGREE OF M.D.

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- By -

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Along practical experience and study of plague have led me to the conclusion that plague is primarily a disease of rats, and only secondarily a disease of man. This thesis brings forward evidence which seems to me to support this view, and tends to show that without rats we should have no epidemics of plague.

If rats are the originators of plague in man, the manner in which they convey the disease is of great practical importance, and evidence has been gradually accumulating for some years which appears to show that in the rat flea we have one of the transmitters - if not the only transmitter of plague from rats to man. But however the disease may be transmitted, if it really originates in rats nothing but the destruction of the rats in an infected area will stamp out the disease; other measures - such as inoculation - may afford some temporary protection but they leave the original source of the disease.
untouched.

Some of the measures adopted in the destruction of rats - most of which measures have been personally tried by me - will, therefore, be discussed.

I may mention that I have been engaged in plague work off and on for some nine years, most of the time in Bombay and Calcutta, but I have also seen the disease in China, and in 1901 I was Chief Medical Officer in charge of all the plague operations in Port Elizabeth, South Africa, and a detailed account of my experiences there forms the basis of this paper.

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General Association of Rats with Plague Epidemics.
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Writers from the earliest times have brought to notice the fact that epidemics of plague among human beings are associated with an unusual mortality among the rats in places where the disease is present.
Probably the first reference to the association of rats with plague is that contained in Samuel, and refers to an outbreak of the disease in Syria about 3000 years ago. It is recorded that the Philistines in order that the plague might be stayed made offerings to the God of Israel of golden images of their humours and golden images of their mice that marred the land. It is also recorded in "Antiquities of the Jews" in regard to pestilence "a great multitute of mice arose out of the earth and hurt them".

The retreat from Pelusium of Sennacherib's army is attributed to an epidemic in which field mice are said to have played an important part; and according to Herodotus a stone statue of Sethon with a mouse in his hand stands in the Temple of Vulcan to commemorate the event.

Rufus of Ephesus in the beginning of the second century A.D. writing of plague in Libya, Egypt and Syria states "One can foresee a plague which approaches by paying attention to the bad condition which the seasons present; to the manner of living less profitable for health and to the death of animals which precedes its invasion."

Avicenna in Mesopotamia says that on the
approach of plague mice and other animals which usually live underground leave their holes and stagger about as if drunk.  

In the "Bhagavata Purana" written more than 800 years ago people were instructed to leave their dwellings immediately they notice a mortality among rats.

In the great Plague of 1348 rats are mentioned as having been affected.

Lodge says that during the plague in London rats and moles forsok their holes and habitation.

Of the Great Plague of London of 1665 Dr. Hodges says that mice and other subterranean animals "leave their burrows and lie open in the air, which is also a certain sign of a pestilence at hand."

Dr. Hutchinson in reporting on Mahamari or Himalayan Plague says that "the outbreaks are frequently associated with, and sometimes preceded by a great mortality among rats - All the Civil and medical officers who have observed the disease lay the strongest stress on this marked characteristic."

Of the general association of an unusual rat mortality with plague in human beings at the present day nothing need be said as everyone knows the fact; but what can now be definitely stated is that the mortality among rats is due to plague,
precisely the same disease as attacks man. It can
now be said positively that in a plague epidemic rats
and men die of the same disease. This, of course,
does not provide any reason for believing that rats
are the cause of plague in man, as both rats and
men might conceivably be infected from the same
unknown source; but if it can be shown that plague
amongst rats precedes plague in human beings it
seems apparent that they may be a possible source
of infection to man. I am aware that the Indian
Plague Commission decided that epidemics of plague
had occurred in India during the present pandemic
where there had been no proof of infection among
rats, but it is necessary to point out that it is
sometimes exceedingly difficult to obtain evidence
of any unusual mortality among rats in India even
when inquiry is made while an epidemic is in pro-
gress, if inquiry is made subsequently, negative
evidence on this point is quite valueless. In the
early days of plague in India the natives paid no
attention to deaths among rats, because they were not
aware that there was any connection between such
deaths and plague in human beings. As instances
of the difficulty which arises in connection with
this matter I may mention Cape Town and Oporto.
When plague started in Cape Town it was positively
stated as the result of inquiries that dead rats had not been found prior to the beginning of the epidemic, yet it was discovered later that they had been dying in thousands for weeks if not months before the first recorded case occurred in man. In this case the Health authorities knew of the connection between rats and plague, and made special inquiries about the rat mortality yet it was only by accident that the true facts of the case came to light. The same thing occurred in Oporto. It was stated there was no rat mortality, it is now known that rats and mice were dying in the docks and their neighbourhood for several weeks before the first case of plague occurred among the wharf porters.

Other evidence that rat plague precedes human plague may now be mentioned -

The Emperor Jehangir (1615-19) in his journal relates how a mouse after running about like a drunken man and rising and falling in a distracted manner died in the courtyard of the house of the daughter of Asaf Khan. The cat seized the mouse and for some days was ill, then one of the female slaves developed plague with a bubo. In eight or nine days 17 people contracted plague and died.
In the Ikbal - Nama, Nawab Mu'tamad says
"a mouse would run out of its hole as if mad, and
striking itself against the doors and walls of the
house would die. Then the plague was in the house.
If the people at once fled they might be saved; if
they stayed the whole village was swept away."11

The epidemic in Kumaon, one of the endemic cen-
tres in India, in 1834-5 was preceded or accompanied
by a great mortality of rats in the village. The
same thing was noticed by numerous doctors in several
of the later outbreaks of plague in Kumaon and
Gharwal.12

In 1836 plague broke out in Marwar in Ragpu-
tana and lasted until 1838. At Taiwali rats died
just before the outbreak of plague in that place and
Dr. Forbes says that Mr. White reports "This death
of the animals attended or preceded the disease in
every town that was attacked in Marwar so that the
inhabitants of any house instantly quitted it on
seeing a dead rat."13

These cases refer to plague in India before
the present outbreak; but the pandemic now running
appears to have started in China, and to have been
spread from there, and it may be as well to trace
it from there. Among European medical men practising
In Southern China the opinion is practically unanimous that the rat mortality is a precursor of plague. The Chinese, themselves, from their observations believe that the disease attacks rats before attacking human beings, and they think therefore that plague is a soil disease attacking first the animals which burrow in the ground. From inquiries I made in Hong Kong I found the opinion was practically universally held that rat plague precedes human plague - Dr. Lowry in 1882 said about the plague in Pakhoi "In nearly every house where the disease broke out, the rats had been coming out of their holes and dying on the floors." There was a large rat mortality noticed in the first affected quarters of Canton before the plague appeared among human beings. Affected rats appeared in other parts of the city before the disease appeared amongst men. In Hong Kong there has always been a great mortality among rats. Dr. Clark, the Medical Officer of Health, has shown that the rise in rat mortality antedates the epidemic outbreak by several weeks.

In the plague in Yunnan 1871-73 the first sign of the disease in an epidemic form was a sickness and mortality among rats. "Nature" in describing plague in China says "Hung Liang-kih in his Peh-Kiang-Shi-Hwa says 'Shi Tau - Nan was notorious for his
poetic gift —— Then in Chau-Chau (Yunnan) it happened that in the day-time strange rats appeared in the houses, and lying down on the floor perished with blood spitting. There was not a man escaped instantaneous death after being infected with the miasma. Tau-Nan composed thereon a poem entitled "Death of Rats," the masterpiece of his; and a few days after he himself died of this queer rat epidemic.

It is practically certain that Bombay was infected from Hong Kong. The epidemic in Bombay began in Mandvi close to the Docks. Rats died in thousands in Mandvi before the epidemic broke out, and the boys used to throw them at each other. Rats then began to die in other quarters of the town, and whenever this happened cases of plague began to appear. Simpson says "In infecting new districts it was observed that the progression of the disease was intimately associated with the migration of rats. It was not the localities to which people were fleeing from infected districts that were showing grave infection, but those to which the rats were migrating." Snow, the Municipal Commissioner of Bombay established in the most decided manner that the propagation of the plague to different quarters of the city, from the first focus to the population immediately surrounding that focus, did not follow
the panic which was produced in the population when the existence of the first cases became known, but took place long after when the rats emigrated, and in the direction followed by them. Jennings says that outbreaks among men have frequently followed those among rats and where infection has been clearly traced to the importation of infected clothing into uninfected villages the epidemics following have been started by rats. As an instance of this he gives the case of a man whose wife died of plague in Bombay, and who left, a few days after losing her, for his native village in an uninfected area, taking her clothes and ornaments with him. Shortly after his arrival rats commenced to die in and about the house. The inmates then sickened and died, the man himself being the 6th. to be attacked. The infection then spread through the whole village. In Mandvi the Inspector reported that in nearly 50 per cent of the houses he disinfected he found dead rats and cats. In 1897 Dr. Godinho, Plague Medical Officer, Bombay, recorded his observation that sick rats are generally found in a locality from 8 to 12 days before the first case of plague occurs among men; and that as the infection amongst rats spreads, human plague follows in its wake. I worked in the native town in Bombay in the early part of
1898 in the next district to Dr. Godinho's, and there can be no doubt of the substantial accuracy of his observation. In fact to one who knows Bombay intimately as I do, it seems almost unnecessary to bring forward evidence to prove that rat plague precedes human plague because year after year for weeks before the recrudescence of the epidemic rats die in Bombay in thousands, a fact known to everyone living in the place. The present Plague Commission has clearly shown that the steady rise in rat mortality is followed in a little time by a corresponding rise in cases of plague among human beings; and when the rat mortality declines it is followed by a decline in human mortality. It has also been most clearly established that the mortality among rats beginning at one part of the town—generally Mandvi—gradually spreads to other parts, and is followed in the most constant and striking way by plague among human beings in those rat-infected districts. With regard to other parts of India, when the infection was carried to Calcutta, and it is noteworthy that Calcutta was infected before intervening places—the rats in one quarter occupied by Bombay merchants began to die, and there were then a few cases of plague. This was the beginning of plague in Calcutta in 1896; and
Simpson thinks that it was especially the measures taken against rats that prevented the disease gaining a lodgment at this time - In the Patiala State rats were found dead in all the villages infected before plague broke out in them.

Passing to South Africa, rats are now known to have been dying of plague in the Cape Town Docks at least as early as September or October 1900. By December the numbers had markedly increased and by January the stench coming from some stacks of preserved meats was such that it was unpleasant to work near them.

On January 27th, the first undoubted case of plague was discovered and it occurred in a store clerk who worked in one of the storage sheds in the Docks. Two coloured boys working in the same shed were then attacked. These three men had for more than a week before assisted in trapping rats and then letting them loose for the dog to chase.

Dead rats were also found under the office. The epidemic in the Cape Peninsula began with these cases.

In 1901 a quantity of military stores and merchandise which had been lying at Cape Town was taken by sea to Mossel Bay. Soon after the landing of the shipments the rats in the vicinity began to

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die, and there were a number of cases of plague among the inhabitants. Dr. Kirton, who was in charge informed me that all the cases could be traced to rat infection.

In Durban in 1902 the same thing happened with a cargo from the Argentine; and East London was infected in the same way from Durban. Graaf Reinet, King Williams Town, Kei Road and Burghersdorp had first plague rats and then plague cases.

It is to be noted that in South Africa before plague appeared everyone was impressed with the connection between rats and plague, consequently a sharp look-out was kept for undue mortality among the rats, with the result, I believe, that in every place where an outbreak occurred it was definitely established that it had been preceded, often for some weeks, by plague among rats.

Koch says that in Uganda plague in man is preceded by plague in rats. He also holds that plague is primarily an epizootic and that epidemics among men are Secondary to, and dependent upon primary epizootics among rats.

Plague was introduced into Asuncion the capital of Paraguay by rats, and plague among rats in the town preceded the advent of the disease among the
inhabitants. Some further particulars of this very interesting case will be given later\textsuperscript{29}. In 1903 plague was imported into Pisco from Mazatlan. The epidemic among men was preceded by an epizootic among rats\textsuperscript{30}.

As regards other countries and places Simpson states that the epizootic among rats was observed in most of the towns and villages in India in which plague became epidemic. The same phenomenon was noticed in the Mauritius, Alexandria, Oporto, Naples, Cape Town, Port Elizabeth, East London, Durban, Sydney, and Brisbane, precedent to and concurrently with plague prevalence\textsuperscript{31}.

To sum up I think it may fairly be taken as proved that in every place where there has been an outbreak of plague (excepting pneumonic plague) and where there have been intelligent observers impressed with the part that rats play in the dissemination of plague, rat plague has always preceded human plague.
INTIMATE ASSOCIATION OF RATS WITH HUMAN PLAGUE.

I now proceed to bring forward evidence which tends to prove that rats introduce the infection of plague into human dwellings and are thus the direct cause of plague in man. Before detailing my experiences and investigations in the Port Elizabeth outbreak, I will quote some cases bearing on this point brought forward by others. I have already quoted a very early case from the Journal of the Emperor Jehangir in which the introduction of plague into a house was due to a rat. Dr. Lowry says that "in nearly every house where the disease broke out, the rats had been coming out of their holes and dying on the floors". At a residence in a large garden on Bandora Hill near Bombay the garden and house were invaded with rats in January 1897, shortly after some of them died, others were killed by cats, and these became afterwards ill. Ten days after, one of the servants of the house, who had not been to Bombay for weeks, became ill and died of plague. Hankin records the case of a mill
in which there were several thousand workmen. Rats were noticed to die in large numbers, 20 coolies were employed to remove the dead rats, out of the 20 no less than 12 contracted plague, while the rest of the workmen and others in the building remained healthy. Simonds records a case where the inhabitants of a village in the Punjab were turned out of their village and placed in camp because of a commencing mortality, among rats. While in camp two women were permitted to visit their home, and found on the floor of their house some dead rats; these they picked up and threw into the street; they returned to camp and a few days later were attacked with plague. In 1903 the Indian Municipal Journal sent a Commissioner to investigate the plague haunts of Bombay. The Doctor in charge of Dhobi Talao District, who had been on plague duty in Bombay for years, in reply to inquiries said "Before plague comes the rats in a house die, then the plague attacks human beings; at a good chawl (house containing a large No. of inhabitants) near here, the rats died on Aug. 4th, the next day the first case of plague occurred, this resulted fatally; since then there have been four deaths. It is a notable fact which
may be verified by close observation that when a locality is infected, rats are found to be more scarce, and such as remain are attacked by plague and die in houses, thus infecting them. Following a rat mortality in houses cases occur among human beings.

Sir Horace Pinching of Egypt in his report for 1903 says "almost invariably in the houses where cases occur and in those adjoining, dead and dying rats are found".

I now purpose giving a detailed account of the first portion of the plague epidemic in Port Elizabeth in 1901. Dead rats were first found on April 12th, and the first human case of plague occurred on April 16th. I was at once sent to Port Elizabeth and from that time onwards until the beginning of August when I was unfortunately compelled to return to England I was in sole charge of the plague operations in Port Elizabeth. Many of the plague cases were detected by me, all of those mentioned in the report I personally investigated. In every case where the dead bodies of rats were found the cause of death was ascertained by bacteriological examination, often by me, in other cases by the Assistant Medical Officers under my supervision. The cases of plague were also verified by bacteriological examination, and I personally performed most of the post mortem examinations made on those who died.
On April 12th six dead rats were found in a stack of mealies (maize) on Harbour Board property at the foot of Jetty Street. These mealies came from the River Plate and were discharged from the vessel in March. A second stack of mealies adjoining the one already mentioned was subsequently found to contain some dead rats. These mealies also came from the River Plate, but by another vessel, and were discharged in February. The piece of ground on which the mealies were placed is close to the jetty and is surrounded by Harbour Board sheds and stores as shown on the accompanying plan. The mealies as well as a quantity of oats and forage stacked on this area belonged to the military authorities. One of the rats found on April 12th was examined by Dr. A. Edington, the Government bacteriologist at Grahamstown, who found considerable numbers of plague bacilli in the organs, and a guinea-pig inoculated from this rat died from plague.

Case 1. April 16th. The patient was a Kafir labourer who had been working on the stacks of mealies standing on the area mentioned. He lived in a large native location outside the town and probably two miles in a direct line from where he worked. No other case of plague had occurred in this location up to the time of my leaving Port Elizabeth on August 21st.
Case 2.-

May 6th. The patient was a Kafir labourer. Between April 12th and May 6th numerous dead rats were found in the area on which the stacks were standing and some were found in all the stores bounding this area. This second patient had been working in these stores. Some of the rats found dead were subjected to bacteriological examination and were found to be infected with plague. This man lived in a second location, about half a mile from the one where the patient in Case 1 was found, but the length of time that elapsed between the two cases shows that the second patient was not infected from the first. No second case of plague occurred subsequently in this location.

Case 3.- May 20th. The patient was a European staff sergeant who worked in "I" store, one of the Harbour Board stores already mentioned as forming the boundary to the infected piece of ground. He was taken ill on May 17th and it was then discovered that for some little time previously he had been sleeping and taking his food in this shed contrary to orders. Dead rats were found in the shed some days prior to the date on which this case occurred; none of these were examined, but about this time rats were reported to be dying in the searcher's office at the Custom House, a building situated within a few
feet of one of the mealie stacks near the jetty and only a few yards from the above-mentioned store, and on May 17th a rat was seen to come out of its hole in the searcher's office and to die on the floor. This rat was examined and was found to contain plague bacilli.

From the date of finding the first case of plague the military and Harbour Board authorities instituted a vigorous crusade against rats. Disinfectants were also freely used about all the sheds, the floors being regularly scrubbed with disinfectants. By my suggestion fences were erected around the stacks of grain and forage with a view to confining the infected rats within them, and as the grain and forage were removed all rats found were killed and the ground was covered with lime. The rat-catcher appointed by the military authorities succeeded in catching a large number of rats. After about the end of May very few rats were to be found either among the grain or in the shed, and the three cases of plague already mentioned were the only ones traced to this primarily infected area. Up to this time dead rats had not been reported from anywhere in the town excepting the area from which the patients in Cases 1, 2, and 3 came, and it was hoped that by fencing in the stacks after infected rats had been found amongst them the infection might
be limited to this area, but the attempt so to limit the infection failed.

Case 4. - May 19th. This patient was a Cape coloured female, living in a good quarter of the town a considerable distance from the infected area. The source of infection in this case was never traced.

Case 5. May 25th. The patient, a native storekeeper, was taken ill on May 24th. He lived in a portion of the town known as the Strangers' Location. It is situated probably, a mile from the infected area already referred to and, unlike the other native locations, is within the town. Some of the "contacts" in this case reported that dead rats had been found in the shop and yard a short time previously. When the floors of the house were taken up three dead rats were found, one being underneath the floor of the room in which the patient slept. Unfortunately, these were destroyed immediately by the inspectors. The patient stated that he obtained most of his goods from one of the large stores in the main street of the town, and in this store a case of plague occurred on June 13th.

Case 6. - May 30th. This case occurred in a Kafir boy who worked in a barber's shop in Jetty Street. This shop is situated about 60 or 70 yards from the store in which Case 3 occurred and is in the same street as the front of the Custom House referred
to under Case 3 and about 40 yards from it. The barber's shop was on the ground floor of a large store, and in this store dead rats were found some days before the boy was taken ill. One of these rats, examined on May 27th, contained plague bacilli. The shop in which the patient worked is situated north-west of the original area of infection, and it seemed from the reports about dead rats received at this time that the infected rats were making their way northwards through the town, and this idea was confirmed by subsequent events.

Case 7.—June 3rd. The patient in this case was a male Fingo living in Strangers' Location and working in a store within a few yards of the place where Case 6 occurred.

Case 8.—June 10th. The patient was a male Kafir working in a private store close to the original area of infection. This man lived in Reservoir Location, which is situated some distance outside the town and nearly three miles from the jetty.

Although no dead rats were reported from the stores in which the patients in Cases 7 and 8 worked there were infected rats in adjoining stores, as shown under Case 6.

Case 9.—June 14th. The patient was a male
Kafir working on one of the lighters employed in carrying cargo between ships in the bay and the shore and was seen on June 14th. He lived at the extreme north end of the town in a place known as Vlei Post. No previous case of plague had been reported within two miles of this place. On June 6th about 30 dead rats were found in a small stable in a timber-yard situated not far from the place where this patient is said to have lived. An examination of one of these rats disclosed numbers of plague bacilli. The forage was then turned out of the stables and the bodies of 170 rats and mice were found. Most of the rats had been dead for some time. How infected rats reached this part of the town still remains a mystery. Shortly after these rats were found a boy who had been working in the stables was reported to be away from work ill and he is said to have died a day or two later in a village outside the town, but his body was never found and is supposed to have been buried on the veldt by relatives.

Case 10. June 15th. The patient was a European male working as a packer in a large private store in the main street of the town. This store is within a few yards of the place where Case 6 occurred. The patient was taken ill on June 13th. Seven or eight days before this a case of caps in the store
was found to contain rats' nests. The caps were badly gnawed by the rats, and a dead rat found on June 8th in this case was sent for examination and was ascertained to contain plague bacilli. The patient and a native boy were sent to turn out these caps and to sort out the damaged ones with a view to their being destroyed. The European contracted plague and developed a femoral bubo; the native did not contract plague. It was from this store that the patient in Case 5 obtained most of his goods, and it seems probable that by means of these goods, or more probably by the carriage of an infected rat amongst them, plague was introduced among the rats in Strangers' Location.

Case 11. - June 19th. The patient was a male Kafir working as a storeman in one of the largest stores in the town situated not far from the stores mentioned in Cases 6, 7, and 10, and living in Strangers' Location. He was taken ill on June 16th. No rats were found in his house and none were reported from the store in which he worked, but undoubtedly there were infected rats in the immediate vicinity of this store, as already shown, and there were probably also infected rats in the vicinity of the house.

Case 12. - June 20th. The patient was a Cape coloured boy employed as a stable-boy in Sea Lane.
This lane is situated about a quarter of a mile north of the store mentioned in Case 10. On June 17th a dead rat was found in the stable and it contained plague bacilli. The boy slept in a small room off the coach-house attached to the stable. The coachhouses and room were thoroughly disinfected and cleansed. Two other stable-boys who worked with the patient were inoculated on June 22nd with Yersin's serum. One of these contracted plague on July 4th, as detailed below.

Case 13.- June 22nd. The subject of this case was a Kafir girl, aged 14 years, whose body was taken to one of the plague officers. The place of residence was never ascertained, but the mother of the girl worked as a washerwoman in the south end of the town and the girl assisted her. In the vicinity of some of the places where the mother and child are said to have worked, dead rats were found in the street (see Cases 25 and 29).

Case 14.- June 23rd. The patient was a Polish Jew who was out of work and who lived in a second-rate store at the north end of the town. Most of the clothes in the store were bought at sales in Queen Street which lies within a rat-infected area. No previous case of plague had occurred in the immediate vicinity of the patient's dwelling.
Case 15.—June 23rd. The patient was a European male, aged 19 years, working as a storeman only a short distance from the place in which Case 6 occurred. He was taken ill on June 20th. He stated that previously to his illness dead rats had been found in the store where he worked. None of these however were submitted for examination.

Case 16.—June 27th. The patient, a coloured boy working in a stable at the south end of the town was taken ill on June 24th. On May 22nd several dead rats had been found in a store within a few yards of this stable. One of them was examined and was found to contain plague bacilli. This store contained second-hand goods, and the proprietor of the stable had complained on several occasions of the condition of the store and the number of rats to be seen about it.

Case 17.—June 27th. This was the case of a European boy working as an office boy in Main-street. The stores at which this boy worked were infested with rats, and dead rats were found on the premises the day after he was taken ill. One of these was submitted to examination and was found not to contain plague bacilli. There were, however, undoubtedly infected rats in the vicinity and probably in the stores, as the store from which the patient in Case 10 was removed was within a few yards of the place.
Case 18. - July 2nd. The patient was a Kafir working in a store within 30 yards of the store in which the patient in Case 3 had lived. No dead rats had been reported from this store.

Case 19. - July 4th. The patient was a European female living in the north end of the town and working in a shop in Main Street about 50 yards from the stables mentioned in Cases 12 and 22. Two dead rats were found in the store below the shop. These were not examined.

Case 20. - July 5th. The patient a Hindoo syce working and living in the military remount camp in the Show Yard at the north end of the town, was taken ill on July 3rd and was removed to hospital on the 5th. This syce slept on some forage in one of the stables, and on turning out this forage about 20 dead rats were found and one of these contained numerous plague bacilli. Most of the forage in this camp had originally been stored at the south end of the town, and it seems probable that infected rats were conveyed with the forage from the south end to the remount camp.

Case 21. - July 6th. This patient was a Kafir working as a labourer in the market. The market is infested with rats and is not more than 70 or 80 yards from the area first found to be infected, but no dead rats were ever reported from the market. This
man lived at the north end of the town, nearly three miles from his place of work and within a short distance of the stable mentioned in Case 9.

**Case 22n. - July 6th.** A Kafir male, working as a stable-boy in the same stable as the patient mentioned in Case 12, was taken ill on July 5th and was removed to hospital on the 6th. This was one of the persons inoculated with Yersin's serum on June 22nd. He slept in a corner of one of the stables. When the stables and coachhouses were cleared out about 50 dead rats were found. Some of these were in the partitions of the stalls of the stables in which this boy slept. Others were found under the floors of the rooms, in one of which the patient in Case 12 slept. One of the dead rats was examined on July 7th and was found to contain large numbers of plague bacilli. It will be remembered that an infected rat was also found in this place on June 17th.

**Case 23. - July 7th.** The patient was a Kafir male working as a stable-boy and sleeping in the remount camp in the Show Yard. He was said to have been taken ill on July 3rd, the date on which the patient in Case 20 was taken ill. Under Case 20 will be found particulars of the dead rats found in this place on July 5th. As a result of these two cases of plague the whole of the Show Yard was
evacuated, and the persons living in it were removed into tents on the veldt outside. No further case of plague occurred amongst the persons so removed until July 30th, and the man who was then attacked was removed as a "contact" in this case and worked in the Show Yard assisting in the cleansing operations after he had been released from the contact camp.

**Case 24.** - July 8th. In this case the patient was a European female, aged 13 years. The source of infection was not traced.

**Case 25.** - July 9th. A coloured female, aged 11 years, living in the south end of the town, was taken ill on July 7th. On several occasions within the previous two or three weeks dead rats had been found in the street within a few yards of the house, but none of them had been examined.

**Case 26.** July 17th. The patient, a Hindoo living in the north end of the town, was taken ill on July 15th. There was evidence of rats in the house in which the patient lived. The actual source of infection was not traced.

**Case 27.** - July 18th. The patient was a Hindoo hawker, living in a street a short distance east of Strangers' Location. A dead rat was found under the floor of his hut, but there was no evidence that it died from plague. A plague-infected rat was, however, found in the street at the back of the patient's
house on July 18th.

Case 22. - July 19th. The patient was a male Kafir working on one of the lighters in the harbour and living at the north end of the town, about 100 yards from the stable mentioned in Case 9.

Case 29. - July 20th. In this case the patient was a coloured boy living in the south end of the town. Some dead rats and mice were found under the floors of the house, but they were too decomposed for examination. This patient came from a house about 30 yards from that in which lived the patient in Case 25. In both cases the patients were children, and no other cases had occurred in the neighbourhood. As mentioned under Case 25, dead rats had been found in the streets in the immediate vicinity.

Case 30. - July 20th. The patient was a Kafir boy, aged 12 years, living at Strangers' Location. Dead rats were found in the streets in the vicinity of this house on July 10th and 13th, and in each case examination showed that they were infected.

Case 31. - July 21st. This patient, a male Fingo working as a labourer in a store in Main Street, lived in the Reservoir Location and worked in an infected area, but no dead rats had been reported from the store in which he worked.

Case 32. July 22nd. This patient was a Japanese female. No definite information could be obtained
as to the source of infection, but she frequented the street from which Case 27 came.

Case 33.- July 30th. This patient, a male Fingo living in the horse kraals in the remount camp a short distance north of the Show Yard, was removed to hospital on July 30th and had probably been ill for three or four days. He was removed to the contact camp on July 7th in connection with Case 23 and was released on the 19th. After this he worked he said, in cleaning out the stables in the Show Yard. These cleansing operations were undertaken by the military authorities in consequence of cases of plague (Cases 20 and 23) having occurred there.

I have detailed all the cases that occurred up to July 30th to show that selected cases have not been picked out in order to strengthen the case against the rats. It seems unnecessary to detail more cases, and I shall therefore content myself with giving the general results of the observations made on the cases that occurred during the remaining three weeks that I stayed in Port Elizabeth.

In connection with Case 27 it may be noted that two other Hindoos living in the same street as, and close to, the patient mentioned in this case contracted plague, one on August 8th and the other on the 14th. The houses in which these two persons lived
were opposite each other and there was frequent communication between the two places. The putrid bodies of six rats were found under the floors in the case of the last patient.

On August 14th a case came from Victoria Street, close to Strangers' Location, and two dead rats were found under the floors. A week later three cases, all of Chinamen, came from a small shop in the same terrace of houses and only two doors away. Under the floor some 20 dead rats were found, and these were proved to be infected. At the time that these three cases were found another case occurred in a European boy living in a good-class house in the same street. The source of infection was not at the time apparent, but it was shown later that a few days before his illness the boy had been in the Chinese shop mentioned and was therefore there just about the time that the Chinese inmates contracted the disease. The relatives of the boy did not contract plague, and no dead rats were found in the house in which he lived.

On August 18th a case occurred in a Kafir working and living in a plantation some distance, probably one and a half miles, south of the town. The workmen lived in three or four huts in the plan-
tation and there were no other houses near the place. About the same time the European foreman working at this place and living in a part of Port Elizabeth from which no cases of plague had come and in which no dead rats had been found died from the disease, and a few days later another native working and living in the same place was taken ill. Dead rats were then found in some forage near the workmen's huts, and some of this forage is said to have come from an infected part of the town.

ANALYSIS OF CASES.

An analysis of the 33 detailed cases brings out further evidence to prove that rats were mainly, if not wholly, responsible for the spread of plague in Port Elizabeth, at any rate during the first four months of the outbreak. This analysis shows that:

1. Relatives of patients did not contract the disease. In only one case did two members of the same family contract plague (see Cases 23 and 33) and in this case the idea that the infection was from man to man is negatived by the fact that the second patient was not taken ill until 20 days after contact with the first. But both patients worked at the same place, and it has been shown to have contained infected rats.
2. "Contacts" did not contract plague. In only two cases did "contacts" of these 33 plague cases contract plague. One case was that just mentioned and the other was Case 22, and in this latter case again the second patient was not taken ill until 14 days after the removal of the first (Case 12) and both patients worked and slept in the same rat-infected dwelling.

3. Neighbours of plague patients did not contract the disease. Had the infection been from man to man the house in which a plague patient lived would have shown itself a centre of infection by persons living in adjoining houses and who frequented the patient's house becoming infected, but this never occurred except where dead rats were found in the patient's dwelling-house.

4. The dwelling-houses of the patients were widely separated, but nearly all the patients worked in the same rat-infected area. The 33 cases were widely scattered over the town as regards the dwelling-places of the patients, and there was not the slightest evidence in the earlier cases of plague that any patients contracted the disease in their own homes. As already stated, the "contacts" did not contract the disease, and the houses in the vicinity of those in which plague patients lived did not become infected until such time as plague rats appeared in the houses.
in their immediate neighbourhood. But nearly the whole of the patients - 29 out of 33 - worked in the area which was proved by bacteriological examination to contain infected rats. It was only when infected rats made their way to the residential portion of the town that cases of plague began to appear amongst persons who did not work in the business part of the town where infected rats first appeared. Of the first 23 cases only one person did not work in a rat-infected area. This exception was a coloured servant, and it was the only case out of the 23 where a patient who worked in the same place as he lived contracted plague, and up to this time only two children had contracted the disease, and both of these worked in the infected area. But as the infected rats were traced to the residential part of the town cases began to occur amongst people who did not work in the town, and this is shown by the fact that out of the next 21 cases eight were those of children under 13 years of age. In no case did any relatives or "contacts" in these eight cases contract plague, while in all cases dead rats - in some cases proved to be infected - were found either in the houses in which patients lived or in their vicinity. The southern part of the town is separated from the northern by a stream called the Baakens
river, and dead rats were found in only two places south of this river, one place being a store and the other in the extreme eastern part of the area. One case (Case 16) occurred within a few yards of the store mentioned, two others occurred in houses situated in streets in which dead rats were found, and one other patient in this area had been working, and probably sleeping, close to where the rats were discovered. The rats in the store were found by examination to be infected. No other cases of plague were found in this part of the town south of the Baakens river. Most of this area is thickly populated by natives, and all the conditions are favourable to the spread of plague if it is conveyed by man-to-man infection. Yet the cases were confined to one part of the area, and to that part in which alone dead rats had been found.

A general survey, then, of the course pursued by plague in Port Elizabeth up to August 21st shows that the disease began in rats found in maize stacked close to the jetty at which most of the goods from over sea are received, and this maize had come from an infected port. As long as dead rats were found on this area cases of plague were traced to it; when dead rats ceased to be found no
further cases of plague were traced to this part. Infected rats then made their way along a narrow strip of land lying between the main street of the town and the sea, and as they passed northwards cases of plague followed in their wake. Again, in this area when dead rats ceased to be found plague cases ceased to occur. Infected rats were then discovered in four different parts of the town - viz: at the extreme north end, at the extreme south end, in the Strangers' Location near the middle of the town, and in the remount camp. At the same time cases of plague began to come from all these places. At the south end only a few dead rats were found and only four cases of plague occurred there, all close to where the rats were found, the rest of that district remaining free. At the remount camp two cases of plague occurred, and these were removed and the camp was evacuated; only one further case occurred among the men turned out of this camp, and this patient assisted in the evacuation operations. The north end of the town and Strangers' Location and its vicinity still contained infected rats when I left, and cases of plague were still coming from those parts.

To sum up shortly, in places where infected rats were found plague cases followed, and in places
where they were no infected rats only four cases of plague occurred, and in these cases the source of infection could not be traced at all. In no case was there direct evidence of man-to-man infection, and in most cases the possibility of it was definitely excluded.

I attach a spot-map of Port Elizabeth, and a plan of the area on which plague cases were first detected.

Before dealing with some cases of plague on ships I should like to mention another case on land which was recently under my care. I was living in a hotel in Bombay at the time. About 25th or 26th February of this year a resident, who lived with his wife and two children in the block adjoining mine, found a dead rat on the window-sill of his dressing room in the morning. His elder child, a girl of 12, had previously been walking about the room with nothing on but a night-dress, and when she called her father's attention to the rat she was standing within about a foot of it. The father took up the rat in paper and threw it into the street. No live rats had been seen in the rooms for some weeks, and food left lying about at night had been untouched in the morning. The parents had in fact by laying poison and keeping cats rid the rooms of
rats as they were rather nervous about them. This particular rat had either run up to the sill and died or been left there by a crow. On 1st. March the child who had found the rat was taken seriously ill, developed a femoral bubo, and died on 7th. March. I diagnosed the case. On 1st. March a native boy who worked for me developed plague and died with an axillary bubo on 4th March. It was found that he was in the habit of sleeping on the ground under a verandah immediately below the place where the rat was found. As showing that the rats in the hotel were infected, on 8th March a rat died on a table in a room close to the one already mentioned. When found it had evidently only just died. It was sent at once to the Parel Laboratory, and was found to be plague infected, 19 fleas were also found on it, and three contained plague bacilli. Prompt steps were taken to destroy the rats, and all their entrances were blocked. No other cases of plague occurred.

I now wish to record some cases of plague occurring in ships. I personally investigated them, and in several cases I, as Assistant to the Port Health Officer of Bombay, had to take steps to try and rid the ships of infection. Most of these cases have not previously been put on record.
On 3rd or 4th May 1902 the S.S. "City of Perth" left Calcutta for Dunkirk. No illness occurred until after leaving Malta about a month later; then one day about 30 dead rats were found in the store-room. Two men, one European and one native, were ordered to throw the rats overboard. Both men contracted plague and both died. A third man (native) who was not known to have handled the rats contracted the disease at the same time but recovered. No other cases occurred. The particulars were given me by the Captain from the ship's log.
The S.S. "Nevasa" left Bombay for Cape Town on 22nd January 1903, calling at Durban. On the voyage between Durban and Cape Town one rat was seen by the 3rd Engineer (who gave me the particulars) staggering along the deck, it was in such a helpless and dazed condition that a native picked it up by the tail and threw it overboard. The day after arrival at Cape Town one native developed fever and died two days later of plague. Four other men developed plague within the next few days, and three more on 20th March. The ship was fumigated and about 300 rats killed. An examination of some of these by the Cape Town Authorities shewed they had plague.

On 3rd February 1903 the German East African Steamer "Khalif" left Bombay for East African ports. All the crew were healthy on leaving Bombay and the usual disinfection of clothing was carried out. On 14th February dead rats began to be found on board. Between the 14th and 20th about 50 were found in the storeroom and forehold. The rats were removed by some of the crew who afterwards died. On 27th Feb, the third officer while on duty on the bridge was found to have high fever and an inguinal bubo. He used to give out stores daily from the store room to the native crew. He died on 4th March, and on the same day two of the native crew were found to be ill and died within 24 hours with buboes. On 6th March
the donkeyman died; on 10th March the butler died with a bubo in each axilla; on 11th March two lascars died, both with buboes, on 14th March the vessel arrived in Bombay. On examination a coal trimmer who had been ill for 14 days was found to have plague with a femoral bubo. The ship was disinfected and all stores destroyed. I obtained these particulars from the ship's log with the Captain's help. The vessel left Bombay again on 22nd March, and I ascertained later that five days after leaving Bombay the Chief Officer and the steward of the ship developed high fever, both became delirious, and both died on the same day, about four days after being taken ill.

On 10th March 1904 three or four dead rats were found in the No. 4 hold of the S.S. "Peninsular" then lying in Bombay harbour. The fact was not reported and the vessel left Bombay for Aden on 12th March, all being well. Between 11th and 14th March about 16 dead rats were found in the same hold, in the store-room, and on the landing place of the ice-room.

On 14th March, Antonio Dias, the iceman, was found to have fever and he died suddenly on 16th March. The ship's doctor considered the case to be plague. Between 17th and 22nd March 32 dead rats were found, all in No. 4 hold, the store room, and on the landing place of the ice-room. On 26th March the vessel returned to Bombay, and I found the second iceman to
be suffering from plague. Both men worked in and about the iceroom. I had the ship fumigated with sulphur and 100 dead rats were found. No other cases of plague occurred on board. The particulars as to finding of rats were noted and communicated to me by ship's doctor.

On 6th November 1905 the S.S. "Ville de la Gloire" a French passenger vessel left Sydney for Marseilles. The vessel had left Noumea for Sydney on 18th October; there was no plague in Noumea, and the Bill of Health said none in Sydney. But the ship's doctor told me that while the vessel was lying in Sydney he saw in the newspapers that some dead rats had been found in the harbour. On 7th November, the day after leaving Sydney, 7 dead rats were found in the forecastle. Between 8th and 27th November about 26 dead rats were found (one or two a day) in the forecastle, storeroom, luggage room and pantry. One was seen to run into the third class dining room and die. On 12th November an Arab fireman was found to have plague-inguinal bubo. On 13th a European fireman developed the disease, on 14th a European sailor, and on 16th another Arab fireman developed the disease. All these cases were landed at Freemantle and the diagnosis confirmed, two died there. On 23rd November another Arab fireman was found to be ill. There were no glands, and the man was considered to have phthisis and malaria. The
vessel reached Bombay on 29th November, and I went on board immediately on arrival to investigate. The ship's doctor supplied me with the particulars given. I found the last mentioned patient obviously suffering from pneumonic plague, a diagnosis the ship's doctor and two other doctors on board were not inclined to accept I sent some of the patient's spatum to the Parel Laboratory, and it was inoculated into a guinea pig which died of plague. The man himself died a few moments after the specimen was taken. I had traps set, and a rat caught was sent to Parel and proved in the same way to have plague. The ship was disinfected and I understand no further cases occurred on the voyage.

The foregoing are cases which I have myself investigated. Other cases from the literature of plague may be mentioned.

Plague was introduced into Asuncion the capital of Paraguay apparently by rats. The account of its introduction is interesting as showing how difficult it may be under certain circumstances to trace the original source of infection. A vessel with rice arrived at Rotterdam from an Indian Port. Some of the rice was transferred to a sailing vessel, the "Zeir." On the Zeir's arrival at Las Palmas dead rats were found among the rice, and afterwards on the voyage two sailors fell ill, one dying suddenly. At Montevideo the rice was transhipped from the "Zeir"
to the S.S. "Centauro" (a river steamer). During the voyage of the "Centauro" from Montevideo to Asuncion dead rats were found on the ship, and three of the sailors died from diseases thought at the time to be pneumonia, typhoid, and pleurisy. A fortnight after the arrival of the "Centauro" there was a mortality among rats in the Custom House at Asuncion. This mortality later spread over the town, and was proved bacteriologically to be plague.

The S.S. "Antillian" left Cape Town with a clean bill of health on 1st February 1901, and arrived at Sydney on 2nd March. On arrival it was found that a sailor was ill, apparently suffering from pleurisy. He died next day. During the night of March 11th-12th, the storekeeper on board fell ill with a typical attack of plague. The bodies of two rats which had been picked up dead on the vessel on March 4th were found to be full of plague bacilli. It appears that on 22nd February 15 dead rats were discovered on board. The vessel was fumigated at Sydney and 83 dead rats were afterwards found. I have already mentioned that there was plague among the rats at Cape Town when this vessel left; there were apparently only about 100 rats on the vessel and yet only a small number of them had succumbed to the disease by the time the vessel reached Sydney, and plague was still progressing slowly among them.
The S.S. "Senegal" called at Alexandria on 23rd August 1901, on her way from Beyrout to Marseilles. The vessel arrived at Marseilles on 28th August, and as Alexandria was infected with plague the vessel was put in quarantine, and all the personal linen, table linen, bedding, boxes, trunks etc. were disinfected. In fact all was done that could be done excepting that no measures were taken against the rats. The vessel remained at Marseilles 17 days, and on leaving passengers and crew were in perfect health. The vessel touched at Corsica, and four days later - on September 18th - one of the sailors fell ill with plague. It was thus 26 or 27 days after leaving the last infected port before this case occurred. Four rats were captured and found to be infected with plague, and by this time a second case of plague had occurred on board. The vessel returned to Frioul and all but 8 or 9 persons were inoculated after being taken ashore. No further cases occurred. 36

In 1903 plague was imported into Pisco by a vessel bringing corn from Mazatlan, where there were at the time many cases of plague. The epidemic among men was preceded by an epizootic among rats. In April many dead rats were found in the neighbourhood of the Custom House and the first individuals attacked - three in number - were employed as sweepers in that place. 37
Plague occurred in Marseilles in September 1903. The outbreak began in a cardboard factory situated at Barnahè, a suburb of Marseilles, and is attributed to the importation of a number of bales of rags from Smyrna. In the rags a few dead rats were found, and the persons first infected were those engaged in handling the bales.

On August 29th 1904 the S.S. "Bishopgate" arrived at Hamburg from Rosario in the Argentine with a cargo of wheat, maize, and bran. On arrival in Hamburg no one on board had plague, but the rats were found infected. The crew were discharged, a fresh crew engaged, and the ship fumigated and cleaned. On arrival in the Tyne on September 20th one man was found suffering from plague. No other cases occurred.

In addition to the evidence of these specific instances, further support is lent to the theory that rats spread the plague, by the fact that it always attacks ports first, is preceded by an epizootic among the rats in those ports, and is generally contracted first by those working about the docks. This would scarcely be the case if plague were carried about by human beings or in merchandise. Ports are merely landing places for passengers and merchandise, both are quickly distributed about the country, and if they carried the plague, infection should occur almost indiscriminately about that country. It never does so, and apparently never has done so.
The first well authenticated pandemic of plague is recorded to have originated at Pelusium in Egypt in 542 B.C. It was a large commercial entrepôt to which merchandise from the East was brought.Procopius in describing the epidemic says among other things "always beginning at the sea coast it spread into the interior." Le Baker de Swaynebrooke describing the epidemic in England in 1348 says "at first it carried off almost all the inhabitants of the seaports in Dorset, and then those living inland" The plague spread from Canton to Hong Kong and Hong Kong appears to have distributed it by sea to India, Australia, Japan, and America. Simpson says "it is remarkable that plague has not spread very far inland in China and that its chief ravages have been limited more or less to that portion of the country near the coast. There are no railways in Southern China and the disease has made no extensive inroads into the interior of the country except in those districts in which their waterways connect them with infected localities." "In the majority of ports it has been observed that without any known entrance of sick persons, and without any history of illness occurring among recent arrivals, the first signs of the disease have been an outbreak of plague among the rats on the quays or in the immediate vicinity of the docks, and that it was among the employees where the rats were dying that
the first cases of plague were discovered."43 "There is no instance in which it has been absolutely demonstrated that merchandise unconnected with its usual association with infected rats has been responsible for an outbreak of plague.44

I have now adduced evidence which I think provides reason for believing that epidemics of bubonic plague are caused by rats, and probably by rats alone. I say "epidemics of bubonic plague" because I do not mean to assert for a moment that isolated cases of bubonic plague may not be caused by other means than rats; and pneumonic plague can certainly be disseminated by infection, and something closely resembling an epidemic of that particular form of plague may be produced. But such outbreaks die out and do not recrudescce. In cases of bubonic plague where careful investigation is made the mortality among men seems to depend on rats, and to be due in some way to them. It seems pretty clear that in the cases I have cited if there had been no rats present there would have been no plague among men.

TRANSMISSION OF PLAGUE

Epidemic plague being, as I consider, a rat-borne disease, it remains to be considered by what means
the disease is transmitted from rat to rat, and from rat to man, and why it is that so few human beings are attacked in proportion to the number of rats that die from the disease. It may be said at once that nothing is known as to how the epizootic originates among rats. It is thought they may be infected from the soil, and Elliot's researches lend some support to this view, but no definite statement can be made on the subject.

There are various methods in which it might be considered that plague could gain entrance to the system, for instance:

1. By the Respiratory Tract
2. By the Alimentary Tract
3. By contact with infected persons
4. By contact with infected clothing
5. By inoculation through minute wounds and abrasions.

There seems no doubt that pneumonic plague can be acquired by inhaling the microbes contained in a pneumonic plague patient's breath. But even in this case close contact and confined air is necessary. It has not been contended, I think, that ordinary bubonic plague is transmitted in this way.

There are many believers in the theory that plague is frequently, probably nearly always, contracted
through the Alimentary Tract, notably Simpson, 46 and Hunter 47 of Hong Kong. But these observers appear to have proved too much, according to them practically every domestic animal contracts plague in an epidemic time. Even if this were the case, they seem to have lost sight of the fact that people do not eat flesh food raw, and that in the case of the Hindus the great bulk of them do not eat flesh food at all. In Simpson’s and Hunter’s experiments no sufficient precautions appear to have been taken to exclude the presence of organisms morphologically resembling the plague bacillus, such as the organisms of hog and chicken cholera, and others. From personal experience of Professor Simpson and his methods of examination I know that he is in the habit of relying too much on the microscopic appearance of organisms in his diagnosis of plague, and this very fallacious method has in the present instance, I have no doubt, as in cases in the past led him into error. It is certain that the results he is said to have obtained by feeding experiments were not obtained by the Indian Plague Commission or by any Foreign Commission sent to India, and attempts made both in the Parel Laboratory at Bombay, 48 and in Natal to verify his results have signally failed.

Dr. Gibson of the Parel Laboratory, Bombay, fed ten rats on small bundles of corn wrapped in pieces
of gunny bag and then soaked in a broth cultivation of plague, which was sufficiently virulent to kill in 36 hours when inoculated hypodermically into rats in the dose of 1 c.c. The bundles of corn were given to the rats in a moist condition, and the supply was maintained for a fortnight. At the end of that time the rats had consumed each from 100 to 150 c.c. of plague culture. They showed no sign of illness. Subsequently each received hypodermically 1 c.c. of the original culture with the result that they all died of plague within 36 hours. 59

The Indian Sanitary Commission of 1899 say "unless the saliva, vomit, faeces, or urine were contaminated with blood, in such patients those secretions and excretions were not diagnostic of pest at all by bacteriological examination." Thomson says that all the Scientific Commissions that visited Bombay failed to find the bacilli in either the faeces or urine; that both laboratory experiments and general experience tend to show that the ingestion of the plague germ is not a general mode of infection; and that there is no evidence to show that plague has spread from one place to another, much less from one country to another by infected grain or other food material. 50 The idea that plague is disseminated to any extent by means of food must, I think, be abandoned.

The contact theory was firmly believed in, in
the early days of plague, but I know of no scientific men who now hold it true. The disease, in fact, seems to be singularly non-contagious. It is well known that when persons are removed from dirty, vermin-infected houses in which plague cases are constantly occurring cases of plague among such removed persons are rare, even though such persons are accompanied by others already suffering from the disease. "Contacts" removed from the most grossly infected areas and who wait on their plague-stricken relatives in well kept hospitals - as they often do in India - rarely contract the disease. Surgeon-Captain Thomson reports that in upwards of 240 instances in the Parel Hospital the friends of the patients attended their sick, and in 20 instances scarcely ever left the bedside, and in not a single instance did the disease spread to the friends. Out of more than 140 attendants on the sick belonging to the hospital staff from time to time, only one sweeper was attacked. A mother ill with plague suckled her infant and it escaped. An infant with plague was nourished on the mother's milk and she was not attacked. A man slept in bed with his stricken brother and did not contract the disease. Those who nurse and wait upon the plague sick are singularly exempt from the disease. This is so well known that in Bombay it is a common saying that a plague hospital is the safest place during an epidemic! I know of only three nurses in Bombay plague hospitals.
who have contracted the disease during the last nine years, and two of these cases occurred in 1897 or 1898. The evidence, indeed, that plague is practically non-contagious is overwhelming.

Infected clothing is credited with having carried plague in certain cases; and it is difficult to avoid the conclusion that the disease has really been so transmitted, but in no case that I know of has the possibility of plague infected parasites in the clothing been excluded. People going back home at the end of an epidemic have slept in infected beds and have worn the clothes of those who have died of plague, yet no general infection has taken place. Bruce in his travels says - The Turks and Moors are known to be predictionists. Secure in this principle they expose in the market place immediately after St. John's day the clothes of the many thousands that had died during the late continuance of the plague, all of which imbibe the moist air of the evening and morning, are handled, bought, put on and worn without any apprehension of danger, and though these consist of cotton, silk, and woollen cloths which are stuffs the most retentive of the infection, no accident happens to those who wear them from their happy confidence. Jennings says that experimental attempts to isolate the virus from probably infected clothing have been attended with practically uniformly negative results.
cially introduced on to fabric it has been recovered after 70 days (Indian Plague Commission) and after 28 days (German Plague Commission).

Inoculation through minute wounds and abrasions was at one time - In India at any rate - believed to be the chief cause of plague, but it is doubtful now whether it is more than a rare cause of the disease. It was thought that the preponderance of femoral buboes was best explained by inoculation through cuts in the feet, and as the natives of India generally go barefoot the explanation seemed satisfactory. But it is now known that in Europeans who always wear foot coverings the proportion of femoral buboes is about the same as in Hindus. In the epidemic of London in 1665 plague attacked so many of the well-to-do classes who wore well made foot coverings, that it was called by some the epidemic of the middle classes. Montenegro says that among thousands of individuals in Bombay employed in the work of disinfection who went about all day barefooted there were very few cases. A considerable number of native soldiers worked with me in the native city in Bombay, they lived outside the infected area, and were not allowed to come into the city unless they wore boots and had their legs wrapped in puttees, but these certainly did not protect them against plague as several contracted the disease, and most had femoral buboes. J. Ashburton Thompson has shown that in Sydney in 1900 in no less than 73 per cent of the 283 cases which exhibited
buboes the latter were found in the groin although all the patients referred to were white, clothed in European fashion, and invariably shod. In 12 patients mentioned by Ashburton Thompson where every possible source of infection excepting their place of work seems to have been excluded, and consequently where they must have been fully clothed when they were infected, all 12 developed femoral buboes, notwithstanding the fact that their hands, arms, neck, face, and in some cases chest were in no way protected from casual contact with deposited infection.

I have not dealt with insanitation as a cause of plague, because it seems clear that insanitation per se cannot be the cause, as there are too many well known cases where sanitary areas have been infected and filthy places and people have escaped. In the House of Correction in Bombay, where cleanliness is brought as nearly to perfection as is obtainable there occurred an outbreak which exceeded in severity that in any of the filthy shawls and tenements around.

It now remains to consider the method of inoculation by means of insects. In 1900 I maintained that the theory of the transmission of plague by means of the flea was the best working Hypothesis advanced up to that date, and since then much evidence in favour
of the theory has been produced and many arguments against it have been refuted. Simond was the first, I think, to demonstrate that fleas could convey plague from rat to rat, but his evidence was not conclusive. I am now assured, however, by the members of the Plague Research Commission at present in Bombay that they have proved beyond all possibility of doubt that the rat flea does convey plague from rat to rat and probably from rat to man. Unfortunately the full details of the evidence are not available. I purpose, however, trying to show first why it is probable that a succori-al insect is the dissemination of plague, and then I will give such evidence as has up to the present been made public.

The Indian Plague Commission say that many of the officers who have had most experience of the disease consider that the principal source of infection is, as would appear to hold true in the case of yellow fever and possibly also of typhus, to be found in the houses into which the infection of plague has been introduced.

The likeness between yellow fever and plague referred to in the report is interesting, because since that time yellow fever, so well known as a disease of houses like plague, has been shown to be transmitted by means of the stegomia genus of mosquitoes. It will be curious if it is proved that the
other disease is also carried by means of an insect.

There are some very puzzling facts connected with the dissemination of plague, for instance:

1. The preponderance of primary femoral buboes. All statistics prove there is such a preponderance, and it has been noted in past times. John Woodall in 1639 said "The pestilential bubo - sometimes lighteth on or near the inguinal swelling but more often lower upon the thigh." The only theory that seemed to explain this was that deposited infection gained entrance into cuts and abrasions about the lower extremities, but it failed to explain the large number of primary buboes in other places.

2. Diseased persons in certain cases appear to have conveyed the disease from place to place, and in certain cases healthy persons who have been in infected districts appear to have done so, and yet, as has been shown, plague is essentially non-contagious.

3. Clothing has certainly conveyed the disease, but the bacillus cannot be recovered from clothes, and when an epidemic declines, clothing, without treatment, ceases to be infectious.

4. Plague has been several times introduced into England yet has never obtained a hold there.

5. Although rats may die by thousands few human beings may be attacked.
6. The disease sticks to infected houses and yet practically all attempts to recover the germ from the soil, dust, and belongings in such houses have failed.

7. Some people appear to contract the disease by handling dead rats, others handle them with impunity.

8. The rat lately dead appears to be highly infectious, when the body is cold it is apparently quite harmless.

9. Most persons who have contracted plague do not appear to have come in contact with rats dead or alive, yet rats are apparently the real cause of the disease in man.

Two facts stand out plainly in the history of plague, that the principal source of infection is to be found in the houses into which the infection of plague has been introduced, and that at certain times and under certain circumstances clothing is capable of conveying the infection.

How does the theory that plague is transmitted by means of fleas overcome these difficulties?

The Indian Plague Commission in their report say that "primary buboes practically always develop in connection with lymphatics which originate in the skin." They further express the belief that the common mode of the entrance of the plague bacillus into the human organism is through the skin in the bubonic and septicaemic forms of plague. This con-
clusion is now, I think, almost universally accepted.

The flea theory seems to quite easily explain the preponderance of femoral buboes, and also explains why primary buboes may occur in other parts of the body. Anyone who has had much to do with vermin infested houses must have noticed that however careful one may be not to sit down and not to handle things unnecessarily it is impossible to prevent fleas from getting on to the legs. In flea infested houses bites occur much more frequently on the legs than on other parts of the body. I have seen the floors of slum houses swarming with fleas and on many occasions when compelled to stay in such places have had rings of bites round both ankles just above the boot tops, while the rest of the body has been free from bites. This also explains why the primary femoral bubo is as common in the well-shod white man as in the bare foot native.

The conveyance of plague by both diseased and healthy persons, and also in clothing is explained by the fact that infected fleas are carried in the clothing and inoculate persons who come in contact with those who are conveying the fleas either on their person or in clothing.

The fact that plague has not obtained a hold in England the same as it has done in India may be due to certain differences in the rat flea prevalent in the two countries. It would appear that the common rat fleas of England and the Continent are Typhlopsylla
Musculi and the Pulex fasciatus especially the former. But the common rat flea not only of India but also of Africa, and Australia is the Pulex Pallidus. The Typhlopsylla musculi does not resemble the human flea - Pulex irritans - at all, and is probably quite different in habits, and attempts to cause it to bite man have failed. The Pulex pallidus on the other hand closely resembles Pulex irritans and will certainly feed on man. The fact that the ordinary rat flea of England will not bite man may well account for the difficulty plague has had in getting a hold in the country.

Man is not the natural host of the rat-flea which feeds by preference on other animals. This would explain why the numbers of human beings succumbing to plague are small in comparison with the rats which fall victims.

If the flea is the active agent in the transmission of plague it explains why houses become infected, and why ordinary disinfection fails to remove the infection; it also becomes clear why the newly dead rat is infectious, and the cold one not, as the fleas leave the body when cold. In cases where persons have contracted the disease without coming in contact with rats, the presence of a suctorial parasite capable of carrying the disease from one to the other is a plausible, and, I think, the only possible explanation.
It will thus be seen that the flea theory is capable of explaining the most puzzling facts in connection with the spread of plague; but after all this is only a theoretical argument and it is necessary to show in the first place that the flea is capable of conveying infection, and secondly, if possible, that it actually does so.

Many observers have found the bacillus pestis in the bodies of fleas. Giuseppe Ziroli found that fleas after sucking the blood of infected mice retain bacilli alive and active for 7 or 8 days and that bacilli are capable of multiplying in fleas' bodies. The bacilli are constantly found in fleas in Bombay, and have been so found in Cape Town, Port Elizabeth, and Australia. Giuseppe Ziroli also says in the same paper that the flea after being starved, after sucking the blood of animals, projects - without withdrawing its proboscis - a stream of blood by abdominal contraction to wash out its duct before sucking afresh. As plague in the rat is a septicaemia it is only natural to suppose that the flea would imbibe bacilli when feeding on a diseased rat.

One of the most serious objections brought against the flea theory was by Galli-Valerio, and Nuttall who asserted that the rat flea would not bite man. But these observers were unaware that they were dealing with a different flea from that prevalent in plague infected countries. Tisdall has shown that Pulex
pallidus, the rat flea common on the Australian coast will bite man freely, and the Plague Research Committee in Bombay has demonstrated the same thing. Tisdall was the first to show that the Pulex pallidus is the common rat flea of Australia; and Liston, who submitted specimens to the Hon. Charles Rothschild, proved that the same is true of India. Further support is lent to the flea theory of transmission by the observation of Tisdall that when collecting different species of fleas infesting rats he had no difficulty during the epidemic of plague of finding many fleas on rats, but as soon as the epidemic was over the rats appeared to be exceptionally free of fleas. The Plague Research Commission in Bombay has noted the same thing. It is a matter of common knowledge in India that fleas come and go in an inexplicable manner. When I lived in the country in India, during certain months of the year the bungalow simply swarmed with fleas. They appeared suddenly and in full force, stayed a few weeks, and disappeared as suddenly as they came. I have observed the same thing in Bombay, and the invasion took place during the progress of a plague epidemic. I do not know the species, but there was no doubt about their ability and willingness to bite human beings.

As regards the direct evidence that fleas will convey, and do convey the disease from animal to animal, I believe, as already stated that Simond was the first to suggest the flea as the transmitter of
plague and to record experiments tending to prove his suggestion. Simonds' arguments in this connection are summarised by the Indian Plague Commission as follows:

1. Plague rats are eminently infective when infested with fleas, and they cease to be infective when they have been deserted by their parasites.

2. Living plague bacilli are found in association with fleas which are taken from plague infected rats.

3. Plague can pass from infected rats to other animals which have not come directly in contact with them or with their infected excretions.

4. Fleas which infest rats will transfer themselves as parasites to men.

The Commission considered that the arguments in favour of the above propositions brought forward by Simonds were not conclusive. But since then other experimenters have made more conclusive experiments. In 1903 plague was transmitted from rat to rat by means of fleas in five cases by J.C. Gaúthier and A. Raybaud. Liston informed me in a private letter in May 1903 that he had succeeded in transmitting plague from rat to rat and from man to rat by means of rat fleas. But the most conclusive evidence is that obtained by the present Plague Research Commission in Bombay. The experiments and investigations by this Commission began in Bombay 1905, and
have been carried on continuously ever since. During that time some 2000 rats per week have been examined. It has been clearly shown as already stated that the rat epidemic begins before the epidemic in man, and precedes the latter definitely and clearly in all its various phases. As early as October 1905 Dr. Turner, the Health Officer of Bombay writing of these investigations was able to say "It is interesting to note that infected rats are absent in those districts where there is no plague"

It has also been shown by the Commission that the Bacillus Pestis is found in the faeces of fleas, and that such faeces rubbed into a susceptible animal's skin will give it plague. Also that fleas on rats are comparatively scarce when there is no plague and that there is a pronounced increase in the number of pregnant female rats preceding and during the early stages of an epidemic. After many experiments and failures with plague infected rats and fleas the instrument by which success was at last attained was the guinea pig. It was found that this animal was an infallible gatherer of rat fleas in infected quarters, and being itself very susceptible to plague it was used not merely to collect the fleas, but to show the effect of infecting an animal by means of these insects. Over 100 rooms were examined in the
following way: rooms were selected in which two or more cases of plague had occurred. Guinea pigs having no fleas on them were placed in the rooms. Next morning the guinea pigs were examined and were found to have from 20 to 100 fleas on them. These fleas were put into a cage with a flea-free animal, the necessary controls being made and in many instances that animal contracted plague and died. In 28.5 per cent of non-disinfected rooms taken in this way the guinea pigs allowed to run free contracted plague and died. In the case of disinfected rooms 29 per cent of the guinea pigs died. Every description of room and every part of Bombay have been thus examined. The fact that fleas taken from these guinea pigs were able to infect animals which had not entered the infected rooms shows that the flea was the infective agent. But other experiments were made to clearly demonstrate this. Rooms were selected in which rats dead of plague had been found: Guinea pigs were placed in these rooms, some of the animals being unprotected and others protected from the attacks of fleas by means of gauze and other expedients. The unprotected animals were attacked by fleas and died of plague, the protected entirely escaped. The fleas were proved to contain plague bacilli. The experiment has been successfully repeated many times. I may mention that many attempts
to produce plague in guinea pigs by putting them into rooms where the soil and other articles were contaminated heavily with plague bacilli, but where no fleas were present failed signally. Another experiment was made in March of this year. A case or two of plague occurred in the village of Sion Koliwada on the outskirts of Bombay. Dead rats infected by plague were found in the houses. The inhabitants were induced to evacuate their dwellings and in each house captive animals were introduced, some protected and some unprotected. The unprotected animals were attacked by rat fleas which were found to contain the plague bacilli, and they died of plague. The protected animals escaped. The gradual progress of the spread of plague from house to house through this village temporarily repopulated by guinea pigs was clearly traced. In each instance the agent of infection was the rat flea. Unfortunately I have no cases to cite showing that the rat flea has infected man. As will be readily understood direct evidence to prove that plague is so conveyed from rat to man is extremely difficult to obtain.

I have now in this Thesis brought forward evidence which, if not without flaw, at any rate goes far to prove that plague is primarily an epizootic of rats, that they are the cause of epidemics of bubonic and septicaemic plague in man, and that the agent by which the disease is transmitted from rat to rat and probably from rat to man is the rat flea.
DESTRUCTION OF RATS

Having considered the relation of the rat to the spread of plague, and assuming that the rat is really the cause of plague in man I purpose concluding this paper with some considerations as to the best methods to be adopted in trying to stamp out plague in a place where it already exists, and in attempting to prevent it from spreading from that place to others. It is evident that persons may be protected against such a disease as plague in two ways; they may be prevented from receiving the infection, or their bodies may be put into such a condition that even if the bacillus gain entrance it will do no harm. There can be no question as to which is the better method if it can be adopted. Inoculation against plague with Haffkine's prophylactic is undoubtedly of great value, but it should be looked upon only as an auxiliary in the war against the disease. It is by no means an infallible preventive, and experience has shown that millions of people will run the risk of plague rather than submit to inoculation. The ideal to be aimed at is to destroy the source of infection. It has been proposed to try and stop infection by preventing rats from gaining access to human dwellings, and special
stress is laid on this method by Ashburton Thompson. But the idea seems quite impracticable. The cities, towns, and villages of whole countries cannot be rebuilt in order to keep out rats, and further, in tropical climates the people practically live out of doors. Protection might be obtained against infection if means could be devised of preventing fleas from attacking man. I have found that Eucalyptus, Creosote, and Oil of Cajuput in Olive or Cocoanut Oil is very efficacious in keeping off vermin even in places where they swarm; and such a mixture and method ought to prove acceptable to the people of India at any rate, as they are particularly fond of rubbing oil into the skin. But the methods mentioned are open to the great objection that the original source of infection remains untouched. So long as the plague rat is allowed to exist the danger of men contracting the disease will be ever present. To eradicate existing plague the destruction of the rat seems imperative, not only in countries where plague exists, but in places liable to infection from those countries. In a country, threatened with the introduction of plague it is of vital importance not only that an attempt should be made to prevent infected rats from getting into the country, but to do all that can be done to exterminate the rats in sea ports so that if plague is introduced the material for its spread will be absent. It seems impossible to prevent the passage
of rats from place to place and from country to country. As instances I have seen rats escape from railway wagons which have travelled closed for some hundreds of miles. I knew another case in Bombay where a lady moved from one part of the town to another: she locked her boxes before moving and kept the keys; on opening one of the boxes containing clothes in the new residence two rats jumped out. The move might just as easily have been to an up country station in India, and then the rats - perhaps infected - would have been introduced into that place from Bombay. I have heard of several other such cases. Dr. Herbert Williams (Port of London) states that he has seen a hundred rats escape from a broken cask landed as cargo. The Manager of one of the largest milling companies in Port Elizabeth states that it is not at all an uncommon occurrence to turn rats out of bags of grain when the bags are opened. In forage many rats are carried ashore and in many other articles of cargo it is not only possible but it is quite certain that rats gain admission to a country. A good deal of stress has been laid on the migration of rats as a cause of the spread of plague, I do not think enough has been made of the fact that they may be carried all over a country in vehicles, in personal luggage, and in packages of various sorts. Even when rats are not actually carried ashore from ships it seems impossible to
prevent them from making their own way on shore. If protectors are placed on cables, chains, and gangways, and it is well known how difficult it is to carry out such a measure efficiently, rats will drop over the side and swim ashore. Even when vessels lie out in the harbour and discharge by means of lighters, the rats find their way ashore in the lighters, or they can infect the lighter rats who in turn convey the disease on shore. It seems certain that the only way to prevent rats from travelling is to destroy them. Every effort should be made to exterminate them in infected ports, and I think no vessel should be allowed to leave such ports until measures have been taken to destroy the rats on board, such measures, or others, to be continued during the voyage. It seems foolish, to say the least of it, to examine passengers carefully and minutely for plague when it is known that even if infected they are rarely the cause of the disease in others, and to take absolutely no steps of any sort against the real active disseminator of plague - the rat.

The destruction of rats being thus, in my opinion, the object to be arrived at I purpose giving some particulars of the ways in which that destruction may be accomplished both on land, and on shipboard. The chief measures adopted in killing rats
are:

1. By the use of traps
2. By making use of the natural enemies of rats, such as dogs, cats, and ferrets.
3. By the use of poisoned food.
4. By introducing a fatal infectious disease among the rats.
5. By using poisonous or irrespirable gases.

I have tried all of these methods and will endeavour to indicate their relative efficiency.

TRAPS - The use of traps is generally attended with rather disappointing results, mainly because no particular care is usually taken when using them, but partly, because in a short time rats appear to get to know the object of the traps, and to avoid them. In skilled hands, however, I have known large numbers of rats to be accounted for by means of traps. Wire traps which will hold several rats at the same time are probably the best; they should be handled as little as possible and plunged into boiling water immediately after rats have been removed from them in order to keep them free from odour. The baits should not be touched by hand and should be changed frequently; those most acceptable to rats appear to be toasted cheese, oatmeal, sunflower seeds, herrings, or bread, oatmeal, &c., on which a few drops of oil of aniseed or oil of rhodium have been sprinkled. One bait will often succeed in enticing rats into a
cage when others have failed. Cabbage leaves on which oil of aniseed or oil of rhodium has been sprinkled are in great repute in some ports, but the use of these oils proved disappointing in Port Elizabeth. Probably the best results were obtained with sunflower seeds. The quantity of food within the reach of rats in all towns is responsible to a great extent for the failure which often attends the use of traps.

**DOGS AND CATS** - No very marked benefits arise from the use of these animals when the wholesale destruction of rats is attempted, but they are useful as auxiliaries.

**FERRETS** - These animals are employed largely in some places, and in the hands of expert rat-catchers good results are obtained, but it is doubtful whether they should be used in places where rats are infected. Twenty ferrets were received in Port Elizabeth from England on July 9th. They were worked systematically from about the 20th. On the 30th, it was noticed that some of the ferrets were sick and on August 1st two died: by the 14th, 16 out of the 20 were dead, and the remaining four, then very ill, were killed. Five of the ferrets that died were examined. A few organisms resembling plague bacilli were found in the organs of the first, in the second nothing was found, and in the other bacilli morphologically identical with plague bacilli were
abundant. The post mortem appearances also resembled those found in plague. A second batch of ferrets died in the same way and with the same symptoms. A septicaemia in ferrets due to an organism resembling the plague bacillus was not quite definitely excluded so that I cannot say for certain that this was plague. But the ferrets used in Cape Town died in the same way, and I heard of none dying with the same symptoms excepting those used in hunting infected rats. The use of ferrets, therefore, would appear to be not unattended with danger, as they may introduce disease among rats not already infected.

**POISON** - This, and the next mentioned measure, are, in my opinion those on which most reliance should be placed for the destruction of rats. The disadvantages of using poison are obvious: most rat poisons will kill other animals, including children, and many persons object to their use on this account. But if care is used the danger can be reduced to a minimum. By laying the poison late at night, taking it up early in the morning, and shutting up domestic pets during the time that it is laid, there is practically no risk of anything but rats suffering from its employment. Another disadvantage is that rats killed by poison often die under the floors of rooms and the stench arising from their decomposition becomes unbearable. There appears to be no way of avoiding this. Some makers of rat poisons advertise
that their poison causes the dead bodies of rats to dry up without emitting any offensive odour, but a poison which really does this has not yet come under my notice. The only reply that can be made to the objection that poisoned rats cause such an objectionable odour is that the odour from dead rats about a place is much less dangerous than the presence of live rats in it when plague is present in the town or likely to be introduced. Most of the advertised rat poisons fulfil the purpose for which they are sold fairly well and some of them give excellent results. A home-made preparation which is highly spoken of is one made by mixing equal parts of plaster-of-Paris and oatmeal together. The addition of a drop or two of oil of aniseed probably makes the mixture more attractive, whichever poison is employed, it should be spread on small baits, untouched by hand, and these should be used systematically, regularly, and over wide areas, not omitting sewers and drains. Very good results are obtained sometimes by dissolving arsenic in water, but great care must be exercised in its use as the water is very apt to be drunk by those for whom it is not intended. In certain parts of Port Elizabeth where poison was used systematically the reduction in the number of rats was most marked, and in some places they appear to have been exterminated. Under this heading may be mentioned some substances which while not being
destructive to rats are yet so objectionable to them as often to cause them to leave the place where they are used; the chief of these are lime, chloride of lime, carbolic acid. As, however, the driving of infected rats from one place to another is more likely to spread plague than to assist in stopping its spread, the use of these substances in places where there are known to be infected rats would not be advisable were it not for the fact that the three substances mentioned are destructive to fleas; hence the scrubbing of floors with carbolic acid is a measure to be recommended, and as fleas lay and hatch their eggs in sand the laying of lime on the ground around buildings is also a wise precaution. The lime should be frequently renewed as it soon loses its strength. Col. King speaks highly of a mixture of sulphuric acid and tar one part of acid to 8 of tar\textsuperscript{80} as being very efficacious in driving away rats. The mixture should be placed in the rat's holes. Ordinary slow drying tar-\textit{varnish} thinned down with petroleum and used in the same way is said to be very good. These methods are better used in advance of plague, or from the unaffected periphery towards the centre of a circle round the first infected houses.

\textbf{THE INTRODUCTION OF INFECTIOUS DISEASES AMONG RATS.} - The only disease at present known which is likely to prove successful is that caused by Danysz's
bacillus; and to be successful it must be used in a special way. If rats are infected with cultures of the bacillus and are then allowed to return to their haunts, it is apparently necessary in order that the disease may spread that rats that have died or are likely to die from the disease should be eaten by their fellows. Rats shut up together in a cage will sometimes eat one another, and they possibly do so to a very limited extent under normal conditions, but it is quite obvious that a method relying on this proclivity alone to cause the spread of the disease was destined to failure; especially when it is considered that when the disease is propagated in this way the organism rapidly diminishes in virulence, and those which contract the disease and live, as many do when infected with a weak organism, are apparently immune from the disease. Even if the disease had been more easily disseminated it is doubtful whether it would have been of more than limited use. Plague, so far as I am aware, is one of the most deadly rat diseases known, but I have never heard of its exterminating rats in any place. If Danysz's method is to be efficacious no reliance must be placed on the spread of the disease from rat to rat, but arrangements must be made so that each rat receives its dose of fresh virulent culture. This is done by distributing small pieces of bread or crushed oats soaked
in a broth culture of the organism. Danysz's early results were not obtained by other observers. Klein and Williams obtained results that were only fairly satisfactory; Kister and Kostgen confirmed Danysz's results from laboratory methods only. Abel of Hamburg considered in 1902 that the method though not invariably efficacious was worthy of a trial. Rosenau from experiments on rats in cages found that only about 40 per cent were killed. But probably many of the unsuccessful results were due to defective technique, and much better results have since been obtained. Danysz reported in April 1904 that a summary of the reports he had received and which numbered several thousands showed that in 60 per cent of the operations undertaken the rats completely disappeared, in 15 per cent the results were negative and in 25 per cent partial destruction was effected. In the same report he gives particulars of the results obtained in Odessa in September and October 1902. The operations were directed by M. Diatroptoff, Director of the Pasteur Institute of Odessa, and he lays special stress upon the need for proper and systematic distribution of the inoculated crusts, and on the necessity of using the infected broth the day it is made. Several weeks after the operations had been carried out the Bacteriological Institute was able to procure only 14 rats alive and
in good health although it offered a reward of 15 Kopecks a head.

In the French Chamber of Deputies complaint was made about the end of 1903 of the immense damage done to crops in certain constituencies by the rats. It was decided to try the effect of Danysz's virus. The operations were under the direction of Dr. Roux, and were begun on 28th January; on 24th February he reported that the campaign had been completely successful. It is estimated that 95 per cent of the rats were slain, their dead bodies were found in the holes in heaps of 15 and 20. These results are encouraging. But to insure success it is necessary that the cultures should be of full virulence and fresh. Unfortunately cultures seem to lose their virulence by being transmitted by sea, and it is not easy to exalt it again. This has happened in Bombay, and I understand that no method has yet been found successful there in increasing the virulence. In Cape Town there was the same difficulty. I tried some of the Cape Town cultures in Port Elizabeth but the results were not decisive, and inoculation experiments seemed to show that the cultures were not as virulent as they ought to be. Danysz, Roux and other observers are agreed that the virus is absolutely harmless to those who handle it, and to all animals other than rodents - a great point in its favour.

POISONOUS GASES - The two gases chiefly employed
are sulphurous acid gas and carbon dioxide. On land these gases can be used in sections of sewers, otherwise they are more useful for destroying rats in ships.

All of the methods mentioned may be used on board ship; but poison, and the use of gases are the two on which reliance should be placed. I am not aware that Danysz's virus has yet been used on ships, but it ought to be successful in cases where a doctor is carried, and it could certainly be used as an auxiliary to the gas method while vessels are lying in an affected port.

It is not necessary to say anything about the use of C\textsubscript{2}O as the use of S\textsubscript{2}O\textsubscript{2} is cheaper, more convenient and safer. C\textsubscript{2}O has the advantage of not being injurious to merchandise, but its action appears to be uncertain, and if chalk and an acid are used to generate the gas it would require a mountain of chalk and an ocean of acid to produce enough gas to properly flood a large vessel. Cylinders of gas are not always available, and if they were the method would still be very costly.

Sulphurous acid gas has given excellent results, and is now in general use. The gas may be produced by burning sulphur in the ordinary way, or it may be generated in a Clayton apparatus. The latter is simple, very convenient, and has given very good results in Bombay where I have used it, and seen it used
by others. The S.S. "Kerbella" was disinfected by
the Clayton apparatus at Bombay in June 1904, and
after the disinfection 120 dead rats and 13 buckets
of dead cockroaches were removed from the vessel.
Similar results were obtained with the S.S. "India"
last year. The apparatus is taken to a vessel on a
barge, and sulphur is burnt in a receptacle connected
with a furnace. From this receptacle flexible pipes
can be led to any part of the ship and to several
parts at once. A powerful fan forces the gas through
the pipes, and at the same time an exhaust fan with-
draws air from the hermetically sealed holds &c.
The air from this exhaust can be tested from time to
time to ascertain the percentage of S.O.² present.
By this method the generation of the gas can be car-
rried on without fail for any length of time. It is
said that the good results obtained from this appara-
tus are partly due to the generation of a certain
quantity of sulphur trioxide. Many observers have
reported on the efficacy of the Clayton apparatus,
as for example, Walford at Cardiff,⁸⁸ Thomas at the
Mississippi River Quarantine Station,⁸⁹ Calmette and
Hauteffeville at Lille,⁹⁰ Haldane and Ward in London⁹¹
It's efficacy is not so marked when there is cargo
in the ship, and especially if there are woollen or
other fabrics done up in tight bales, as these fabrics
possess a peculiar power of absorbing the gas in
their outer layers. Metals are tarnished by the gas
but might I think be protected by applying a little grease or oil. Certain food-stuffs are rendered unfit for consumption by absorption of the gas. I have not found that the decorative work in the saloons of steamers is injured.

When the Clayton apparatus is not available, burning sulphur in the ship can be resorted to. I have found that the best way to do this is to use a charcoal brazier, something like a bucket on short iron legs. This vessel is half filled with glowing charcoal and the necessary quantity of sulphur placed on top. These braziers are convenient and safe. They can be carried about by a handle, any number of them can be used in any part of a ship, and the use of the red hot charcoal ensures the complete combustion of the sulphur, while adding CO₂ in addition to SO₂ to the atmosphere. I disinfected the S.S. "Peninsular" - already mentioned - in this way, and the results were very satisfactory, 100 dead rats were found, and no live ones were seen afterwards, while the holds and decks were covered with deep layers of dead cockroaches. To ensure the complete destruction of rats on a ship the ship should be completely sealed up, including the funnels (frequently overlooked), and the whole done in one operation; otherwise rats make their way from the parts being fumigated to those not yet done, and return to the first part when the fumigation of the second is being

82.
carried out.

In conclusion I should like to quote the opinion of Tsukiyama, Chief of the National Board of Health in Japan, as regards the results we may hope to obtain by the destruction of rats. He considers that it is possible to exterminate the plague in infected cities by destroying rats systematically. In support of this view he points out that plague was arrested in a few months in three cities, and was exterminated in the case of a fourth (Tainan) after it had prevailed for seven years.\textsuperscript{92}

I am of opinion that the suppression of plague in any country where it is \textit{epidemic} can only be brought about by the destruction of rats in infected places.

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PLAN OF PORT ELIZABETH.

DONALDSON & HILL'S

REVISED TO DATE.