PLAGUE IN THE ORIENT WITH SPECIAL REFERENCE TO THE MANCHURIAN OUTBREAKS.

By WU LIEN TEH, M.A., M.D., B.C. (Cantab), Litt.D. (Peking), LL.D. (Hongkong). *Director and Chief Medical Officer, Manchurian Plague Prevention Service; President, International Plague Conference, Mukden*, 1911.

Plague is essentially an oriental disease, and whether Dr W. J. Simpson be right or wrong in naming China's south-western province of Yunnan as its primary focus of infection, there is no doubt that since the great pandemic of 1894 the endemic areas have increased both in number and extent. The vast Empire of India with its 320 million people may be considered permanently infected, although certain administrative areas like the Punjab, the Presidency of Bombay, and the United Provinces of Agra and Oudh suffer to a greater extent than the hilly Province of Assam where during the last six years only one case has been recorded. During the last 18 years, over ten million persons have died of the pest in India alone. In other parts of Asia frequent outbreaks of plague have occurred during recent years, *e.g.* Ceylon, Straits Settlements, Dutch East Indies, Siam, Indo-China, Japan, Hongkong, the provinces of Kwangtung and Fukien (particularly at the ports of Canton, Swatow, Amoy, Foochow), Manchuria and Siberia. The coal mining centre of Tongshan three hours by rail from Tientsin was infected by some bubonic cases from Hongkong in 1898 and lost a thousand lives in four months. The port of Newchwang (Yinkow) in South Manchuria was invaded in 1899 (probably again through vessels from the south) and lost in five months 2000 people. From 1901 to 1903 isolated cases were detected, but they never resulted in an epidemic. It is strange that the great pulmonary epidemics of 1911 and 1921 did not touch either Tongshan or Yinkow, although both lie on the main highway of railway traffic.

Although favourable results have been obtained by the application of modern preventive methods in such places as the Philippines and Japan, the total suppression of Bubonic Plague appears to be an ideal still to be achieved by interested governments. The following mortality figures show how widespread is the disease in different parts of the Orient.

Passing on to China, we find that statistics are difficult to obtain from any part except Shanghai and Manchuria, the former controlled by an efficient Health Department of the International Municipal Council, the other by the Manchurian Plague Prevention Service. Shanghai with a population

Table I. *Plague Invaded Areas in the Orient.*

Location	Years	Year of Severest Infection	Total Plague deaths	Aggregate population
India	1896–1917	1907	9,841,396	320,000,000
Ceylon	1914–1917	1914	978	800,000
Straits Settlements	1910–1917	1917	280	1,000,000
Dutch East Indies	1911–1917	1917	34,732	40,000,000
Siam	1911–1917	1916	1,063	9,000,000
Indo-China (French)	1911–1917	1913	14,911	18,000,000
Hongkong	1895–1917	1914	15,731	520,000
Japan	1907–1916	1907	1,380	50,000,000
Formosa (Japan)	1896–1917	1901	24,108	3,400,000

of close upon a million reported only 61 human cases and 1108 infected rats in the years 1910–19. The years 1916–19 were entirely clear.

In the two southern provinces of Kwangtung and Fukien, epidemics of greater or less severity occur almost yearly, but up to the present no reliable records have been published. It is hoped that with the recent establishment of a Ministry of Health attached to the southern government containing a responsible medical man in charge we may look forward to more accurate information during the coming years.

The incidence of plague among a population or community seems to depend as much upon the locality, its climate and humidity and character of inhabitants, as upon the preventive measures employed. For instance, as far as India is concerned, the mortality curve reaches its highest point in March and its lowest in July. This periodicity has been demonstrated to be due to the humidity of the earlier months of the year—humidity being favourable to the life of the flea. In spite of the efforts of the government to deal with native prejudice and well-directed measures to control the malady, it has continued to rage year by year with almost unabated severity up to the present time. On the other hand, we see steamer traffic taking place regularly between the endemic southern ports of Canton, Hongkong, etc. and northern ports like Shanghai, Dairen, Chefoo, Tientsin, Newchwang, etc., and yet plague seldom visits these parts, although the number of infected rats in the holds of the steamers must be considerable, and ordinary anti-rat precautions such as disc guards, tarred ropes, are not rigidly enforced when these ships are moored alongside the wharves.

With the exception of some accidental cases, the epidemics referred to above have been of a bubonic nature, propagated by means of and through the agency of the rat flea. As found in India, whenever the seasons are most humid, fleas abound and the incidence of bubonic plague becomes greater. The prevention of plague in these regions therefore lies principally in the destruction of rats, the rat-proofing of houses and the proper supervision of possible rat-infested merchandise, especially grain, which certain authorities regard as more dangerous vehicles of the infection than human beings.

The Manchurian Outbreaks.

When we turn to the series of epidemics known as the Manchurian outbreaks we deal clinically and epidemiologically (except that the causative organism is the same) with a totally different disease. In this type of plague the part played by the rat and its flea is negligible, beyond the fact that the early cases are probably secondary manifestations in the lungs of the bubonic infection, which in a favourable environment, such as is met with in the crowded semi-underground inns of North Manchuria, readily follows a purely pulmonary course. It is quite possible that the tarabagan or Mongolian marmot (*Arctomys bobac*)[1] found in large numbers on the Siberian and Mongolian plains may, like the domestic rat, harbour the plague bacillus (our latest experiments on these animals to be mentioned later on seem to support this view) and are the real precursors of epidemics of plague pneumonia. So able an observer as G. W. McCoy has stated "Pneumonic Plague in man rarely occurs from rat infections, and it is an interesting and possibly significant fact that in plague squirrels there is a very definite tendency to pulmonary localization, a condition which never occurs in plague in rats[2]."

Russian observers have sturdily clung to the idea of plague arising from the skinning and eating of tarabagan flesh, so that whenever a case is reported in Siberia the inevitable "after having partaken of the flesh of tarabagan" follows. At the moment of writing (20 August, 1921), some new cases of Bubonic Plague have just been reported from Dauria in the Transbaikal regions, the first two being in a Russian station master and a signal man, who both developed cervical buboes after having skinned and eaten tarabagan flesh. Careful enquiries made by our Medical Officer on the spot have elicited the information that these two men skinned as well as ate the flesh while four others who only ate the flesh did not fall ill. Three more cases have been reported in that region, including a doctor who operated on the bubo of the station master and developed plague septicemia. It will be interesting to see whether any pulmonary case will result from this local outbreak as we may then have some ground for connecting the tarabagan with pneumonic plague in man. My own researches in Mongolia in 1912 failed to record a single authentic case of direct tarabagan infection in man, and until further evidence is produced one is obliged to come to the conclusion that the Manchurian epidemics have arisen as a result of primary bubonic infection invading the lungs in addition to other organs. Whether the wild tarabagan or the domestic

[1] Tarabagans and their haunts are figured by the author in *Journ. of Hyg.* XIII, Pls. VIII–XVI (1913).—Ed.

[2] This statement will require modification in view of some interesting localised pneumonic-plague epidemics recorded, *e.g.* Br. freight steamer *Friary* (which had 8 deaths out of a crew of 21 in 1901), Br. mail steamer *Nagoya* (which had 8 deaths out of a crew of 195 in 1919), two epidemics in the Gold Coast in 1908 and 1917, and others. (G. W. McCoy. *American Journ. of Hygiene*, I, No. 2. The problem of Plague in the United States; *Annual Report, Ministry of Health*, London, 1919–20; *Lancet*, 25. x. 1919.)

rat plays the more important part in this endemic region in distributing the disease still requires to be worked out, and it must be confessed that our attempts at finding infected rats in Manchouli, Hailar, Harbin and Mukden (all situated in Manchuria) have been as devoid of positive results as our attempts at finding plague infected marmots in their underground quarries in Mongolia.

That the Transbaikal region is endemic for plague may be judged from the accompanying Table II. (In the *Journ. of Hygiene*, XIII, pp. 237–290, 1913, I have summarised the period 1898–1910, showing plague to have occurred every year in the Kirghiz Steppes, a vast stretch of territory extending from Astrakhan in Europe to Uralsk and Semiretchinsk in Asia.)

Table II. *Plague Years in Siberia and Manchuria.*

Year	Season	Locality where plague present	Type	Mortality
1910	Sept.	Dauria (Siberia)	Bubonic and pneumonic	40
1911	Oct.–April	Manchuria and N. China	Pneumonic	60,000
1912	—	No record	—	—
1913	Aug.	Kirghiz Steppes	Bubonic	Not ascertainable
1914	Oct.	Transbaikalia	Bubonic	13 (out of 16)
1915	—	No Report	—	—
1916	Sept.–Oct.	T'aochow in Kansu	Penumonic	About 60
1917	Sept.–Dec.	South Mongolia	Pneumonic and bubonic	Not ascertainable
1918	Jan.–April	8 provinces (S. Mongolia, Suiyuan, Chahar, Shansi, Chihli, Shantung, Anhuei, Kiangsu) offshoot of 1917	Pneumonic	16,000
1919	Sept.	Ikievskaya (Transbaikalia)	Bubonic	2
1920	Sept.	Abagatui (Transbaikalia)	Bubonic	5 (out of 6 cases)
1921	Jan.–May	N. Manchuria and Chihli and Shantung (offshoot of above)	Pneumonic chiefly only 12 bubonic observed	9000
1921	Aug.	Dauria, 40 miles west of Manchouli	Bubonic	6

It will be seen from the above that the three great epidemics occurred in 1910–11, 1917–18 and 1920–21 when 60,000, 16,000 and 9000 persons died respectively. As I was directly responsible for the management of the first and third epidemics, I will deal with them fully here. The first epidemic found China absolutely unprepared, for until our staff arrived there were no hospitals and no proper sanitary staff to cope with the emergency. The Central Government had, however, considerable power over the provinces, and when I applied for the necessary funds, medical assistance, and permission to perform post mortems and to cremate the dead, all was rapidly given, and by April 1911 the whole epidemic from Harbin southwards as far as Shantung had been stamped out. When the 1920–21 outbreak came we were much better prepared, for the Manchurian Plague Prevention Service had been established for nine years, and the officials and natives had more or less understood the nature of our mission, so that, although some trouble was caused by unruly soldiers and the ignorant masses led by a few professional agitators, our anti-plague measures met with general approval. Only four cities reported a high mortality (Manchouli, Dalainor, Tsitsikar and Harbin) claiming 7000 out of the total 8500 deaths in Manchuria. The epidemic was confined to

North Manchuria, practically all places south of Changchun escaped and only 300 cases occurred in the two provinces of Chihli and Shantung.

Table III gives a comparison of the two epidemics regarding first case reported and total mortality in each district.

Table III. *Two Epidemics compared.*

	1910–11		1920–21	
City	1st case	Total mortality	1st case	Total mortality
Dauria (Siberia)	Sept.	40	Sept.	5 (Abagatui)
Manchouli	,,	400	Jan. 21	1141
Dalainor	Oct. 19	120	,, 13	1047
Hailar	,, 27	3	Oct. 22	98
Tsitsikar	Dec. 4	600	Jan. 18	1734
Harbin	Oct. 27	9000	,, 22	3125
Hulan	Dec. 13	4000	Feb. 7	322
Shwangchengpu	Jan. 5	1500	Mar. 14	134
Changchun	Dec. 31	5000	Jan. 31	77
Kungchuling	Jan. 15	35	,, 31	5
Mukden	,, 4	4500	Mar. 29	4
Dairen	,, 4	66	—	0
Chefoo	,, 21	400	May 3	24
Tsinanfu	Feb. 1–7	450	—	0
Vladivostock	—	0	April 9	520

As showing how the migration of population affects the spread of the disease, two points may be stated. (1) In the 1910–11 epidemic there was no definite anti-plague authority and no cooperation between the various railway lines operating in these areas. Sick patients and persons incubating the disease spread the infection broadcast, and thousands of victims were reported in all large cities between Harbin and Tsinanfu (Shantung). It was quite common to find a dozen cases in the trains on the South Manchurian and Peking-Mukden lines. One notorious car conveying 39 sick to Tientsin and Peking was sent back to Mukden, and it was the sorting out of these cases that probably caused the death of the young British doctor Jackson. In 1921 we made timely arrangements with the railway authorities regarding restriction and control of the passenger traffic and so saved thousands of lives. (2) In 1911 very few coolies travelled eastwards from Harbin to Suifenho and Vladivostock, and hence no cases were reported at either place. In 1921, however, owing to the opium boom, 800–1000 third and fourth class passengers were travelling in that direction daily to cultivate the fertile regions. Although the inspection of passengers was enforced at Harbin station, several persons incubating the disease escaped detection and developed symptoms on arrival at different towns. Fortunately, these were isolated instances, and only Vladivostock suffered to any great extent claiming 520 deaths up to July, among them some human bubonic and rat infections.

Seasonal prevalence. When we study the seasonal prevalence of the epidemic, we find that on both occasions it originated in September (the one at Dauria and the other at Abagatui, two Siberian villages). The first outbreak continued without any interruption at Manchouli and passed on to the other cities until its suppression in the following April. The second

outbreak did not show its full virulence until November at Hailar, where I personally examined the early bubonic cases and saw their gradual evolution through the septicemic into the pulmonary form. It was the liberation of nine contacts by the local soldiers after their attack upon the Chief of Police and the escape of some to Dalainor that led eventually to the general epidemic, for in the windowless insanitary underground dwellings of the miners, 40–60 of whom were herded together in double tiers within an area of 40 ft. by 20 ft., the *Bacillus pestis* found indeed a fruitful soil. From Dalainor cases travelled to Manchouli, Tsitsikar and Harbin, where strong measures had been taken to protect both the local people and places further south by the inspection of trains as well as by quarantine for five days of the restricted number of third class passengers at Changchun. The poorer members of the community, however, did not understand the value of preventive measures and refused to report cases. When any one got sick, he was hidden until dead and then thrown out into the street at night-time, or else he was driven out at the last stage with the injunction not to report his address, for fear of the contacts being sent to the observation wagons. This unnecessary fear of the anti-plague officers extended even to the educated classes, for one of the corpses found in the streets was identified as that of the Vice-Chairman of the native Medical Society whose wife preferred this treatment of her dead spouse to being isolated.

SOME PROMINENT SYMPTOMS. DANGER TO CONTACTS.

It is not my purpose in this paper to travel over old ground but to allude to the more interesting and rarer features of the disease. Like other insufficiently studied affections, Pneumonic Plague grips the interest of the research worker, not only because of its extraordinary virulence, its simple direct means of infection and its equally simple method of control (if only the human machine were not such a complex psychological and withal obstinate factor) but also of the possibilities of immunisation.

After an incubation period of two to six but commonly three days, the patient feels drowsy and dizzy with headache and lack of appetite. He complains of a chilly feeling and develops a moderate temperature of 102–3° F. and fast soft pulse. This condition usually lasts for 24 hours before cough sets in, at first dry but quickly accompanied by liquid frothy sputum tinged with bright red blood. In a fair percentage of cases the haemorrhage is considerable, the floor and bedding being profusely covered with blood, while occasionally the patients die without experiencing any cough or haemoptysis. The period intervening between the appearance of the fever and the first sign of cough is most important for those in charge of contacts, because this is the non-infective interval when the sick may be removed without endangering the others. As soon as cough appears the danger of infection becomes greater. This is well illustrated in the case of our late Dr Yuan Teh-mao, who was infected while serving as chief of the house-to-house inspection squads. O

the fifth day after exposure, though feeling unwell and probably feverish he still attended a crowded sanitary conference of 26 people and moved among our medical staff the whole day. That night he was sent to bed because the thermometer registered 102° F. and the next morning *B. pestis* was found in the slight sputum coughed up. Not one of the sixty persons with whom he mixed became ill. Table IV, illustrating the percentage of plague cases among contacts confined in our isolation cars at Harbin shows what a small percentage develope the disease if properly cared for. Incidentally, it points out that during the height of the epidemic (March and April) when the assistants were dealing with an unusual number of contacts the percentage of infection was higher.

Table IV. *Mortality among Contacts in Isolation Wagons.*

Month	Number admitted	Sent to hospital	Plague	Non-plague	Per cent. plague
February	547	47	34	13	6·2
March	911	118	92	26	10·1
April	485	57	47	10	9·7
May	78	5	5	0	6·4
Total 4 months	2021	227	178	49	8·1 (aver.)

These figures compare very favourably with those of Dalainor, where owing to incomplete organisation and the obstinacy and disobedience of the mining coolies 144 out of 655 contacts registered in February and March, *i.e.* 21·8 per cent., died of plague.

Plague carriers. In such a deadly infection as Pneumonic Plague the question of carriers naturally invited our attention. The discovery of the first authentic case was accidentally made when dealing with the first batch of contacts.

Chang I, aet. 27, motor-car driver, was admitted to Harbin Isolation ward on 1st Feb. with 18 others from an inn where one man had died of plague. On 2nd Feb. complained of headache and slight fever. Sputum apparently normal showed suspicious bacilli same day. Cultivations examined next day were impure, but the majority looked like *B. pestis*. On 7th Feb. this impure culture (whole agar slope) was inoculated intraperitoneally into guinea-pig. Eighteen hours afterwards the guinea-pig died, and smears from heart, spleen and peritoneum showed *B. pestis*. Cultures from same all showed pure *B. pestis*. On 6th Feb. after he had been apparently well for four days, swabs were taken from his sputum and tonsils. Culture from the sputum was inoculated into a guinea-pig which died 24 hours afterwards. Smears and cultivations from spleen, heart and peritoneum gave positive results.

One of the 18 contacts, Wang, died unexpectedly on the evening of 6th Feb., *i.e.* six days after his last contact with the first sick man. As the incubation period of Pulmonary Plague is seldom above five days, it is possible that Wang might have been infected by the carrier Chang who harboured the bacilli for at least a week.

After this event, 24 other examinations were made for possible carriers between 1st and 30th March, but in only one instance did we obtain positive results.

Chang II, aet. 30, coolie, was one of four contacts examined on 4th March. Sputum appeared normal and cultivations were made. Growth 48 hours after showed suspicious bacilli. This was inoculated subcutaneously into a guinea-pig on 6th March, which died 24 hours after. Smears from heart, spleen and lungs were all negative, but cultures from the heart showed several colonies and from the spleen one colony. Another guinea-pig inoculated intraperitoneally with this heart culture died in 24 hours with positive findings in heart, spleen and peritoneum.

One girl examined on 26th March also showed *B. pestis*, but she developed the disease before the end of the incubation period and her case was therefore disregarded.

It is premature to say how far the question of carriers influences the course of a pneumonic plague epidemic but this is the first occasion on which the matter has been scientifically worked out.

Infectivity of sick rooms. The illness of Dr Yuan on 17th–20th February in our new hospital block (steam heated and maintained at 17° C.) enabled us to make the first investigation regarding the infectivity of the sick room *per se* immediately after the death of the patient. For this purpose:

Twelve guinea-pigs, two in each tin bucket were placed on the wooden floor of the room (12 by 12 by 10 ft. with one large closed window) for periods ranging from half to four hours. Nothing was previously disturbed and the door was not opened except when the animals were removed at certain times. Only two guinea-pigs died, the first which had been exposed for one hour dying on the fourth day, and the second which had stayed half-an-hour dying on the seventh day. The other ten remained healthy. Autopsies confirmed septicemic plague with congestion of lungs in both animals.

Eight guinea-pigs in lots of two were exposed on 2nd March to air of sick room, half hour before, half hour after, one hour and two hours after death of patient. One animal died on 17th March (*i.e.* 15 days after exposure), showing no bacilli on smears of organs, though pure cultures from the blood were obtained.

Four guinea-pigs were allowed to stay in the plague room from 5th–9th April, where six patients had successively come in and died. One animal became sick, and on being killed showed lesions in the respiratory organs. No tonsillar or glandular infection was noticed. This experiment was performed on behalf of a Russian bacteriologist who at first believed the primary seat of infection to be situated in the tonsils.

Seven other experiments were performed with ten rabbits and 28 guinea-pigs by placing them in sick rooms both before and after the patients died, and also in coffins containing clothes freshly removed from the dead, but in no case did the animal die. One rabbit showed pneumococcal infection.

Similar experiments were also conducted at my request in March at Dalainor by Dr E. T. Hsieh, who exposed ten young rabbits at heights varying from 1–8 ft. to the air of a room (10 by 10 by 12) recently vacated by four dead. They were all living on the seventh day.

These experiments seem to indicate that the sick room by itself or even when occupied by plague patients is not particularly dangerous except when one is standing in the direct line of the spit or droplet. They also raise the question of the need of spending so much energy and money on disinfection of houses, as well as the wisdom of burning infected quarters, which was done so extensively in the 1910–11 epidemic.

Infectivity of railway cars. We have on record four occasions on which a plague patient suffering from fever and cough was found in a crowded railway car running between Harbin and Changchun. The first was on 2nd Feb. when a dying man with haemoptysis was discovered at Yaomen in the train leaving Changchun for Harbin. The other 47 passengers were forthwith conveyed to Harbin for observation but all remained healthy and after six days were liberated. The next two happened on 16th and 20th Feb. when 37 and 47 persons were similarly observed without subsequent illness. The fourth case occurred in the middle of March, and here also none of the 30 contacts developed the disease though all had been in the wagons with the sick man for over nine hours. The distance between the two cities is 150 miles.

Efficacy of gauze and cotton masks. It has been pointed out by Barber and Teague[1] that the simple gauze and cotton mask introduced by me and recommended by the International Medical Conference of Mukden 1911 for pneumonic plague work is often pervious to a spray of *B. prodigiosus*. Dr J. W. H. Chun working in our Harbin Laboratory with *B. lactis* obtained similar results. It must however be remembered that in the plague wards one does not stand within a distance of three feet in the direct line of the breath of the patient, and that quiet breathing or an occasional cough is unlike the continuous spray used in the experiments.

To satisfy ourselves further, we made a series of cultivations from masks which had been used in the wards by the doctors and assistants for various periods ranging from half to four hours. The outer gauze layer, the inner gauze layer and the intervening cotton wool were all tried. In only one sample out of 15 investigated was a positive culture obtained, namely from the outer layer of the gauze which had been worn continuously for three hours. Nevertheless, in view of Dr Yuan's accident, we considered it best to adopt besides the mask a new precautionary measure in the form of a hood made of cloth with a square piece of silk (4 by 6 inches) sewn on in front to protect the respiratory entrance. This hood had two apertures for the eyes and was tucked inside the overall at the neck. With the exception of Dr Yuan, none of our physicians or dressers numbering over 80 met with accident.

[1] *Philippine Journ. of Science*, VII, Sect. B, pp. 255–268.

Experiments upon sputum of patients. These were many and dealt with the action of direct sunlight, indirect sunlight, drying under different conditions, sulphur fumes, formalin vapour, and over a dozen kinds of antiseptics and disinfectants upon the fresh sputum. A detailed list of our findings would consume too much time. Suffice it to say that in at least four samples of sputum exposed in bulk on a petri dish to the sun for 2–6 hours till they appeared dry to the naked eye we could still cultivate the *B. pestis* by scraping the remains.

With regard to fumigation we found that one average expectoration of plague sputum placed in a petri dish in a room measuring 10 by 10 by 10 ft. was more favourably acted upon by sulphur fumes than by formalin vapour. Out of 17 observations made upon the former with exposures varying from 4 to 24 hours we could only grow *B. pestis* on one occasion (four hours). Out of 20 observations upon formalin vapour, we obtained cultivations in eight cases (4–24 hours). Light clothes and overalls, owing to their porous nature were quickly sterilised by formalin vapour, hence formalin gas was generally used for overalls, spirit for hands and gloves, while moist SO_2 was employed for fumigation of houses.

A large number of experiments have in the past been performed upon cultures of *B. pestis*, but so far as we know this is the first time that a systematic attempt has been made to test the efficacy of antiseptics and disinfectants upon the actual plague sputum. Our experiments were made as follows:

Experiment A. Small cotton swabs mounted on iron wires were placed in test tubes and sterilised by dry heat. 5 c.c. of fresh solutions of the antiseptic in different strengths were placed inside each tube. At the right moment the swab was dipped into the sputum contained in a petri dish, suspended in the antiseptic solution for the requisite number of minutes and then washed in sterile normal saline to remove excess of antiseptic. After this, the swab was introduced into a fresh agar tube and a cultivation made. The same proceeding was repeated with the other solutions, care being taken to allow for as little discrepancy as possible in the quantity of sputum tested. The cultures were examined as a rule after 48 hours in the incubator kept at 30° C.

In this way 433 observations were made extending over a period of two months. The chemicals used were carbolic acid, mercuric perchloride, lysol, izal, phenoid disinfectant, potassium permanganate, hydrogen peroxide, lysoform, antiformin, rectified alcohol, methylated spirit, lime-water and slaked lime. The time of immersion varied from 1 minute in the case of alcohol to 30 minutes in the case of antiseptic solutions. Our findings were rather surprising. For instance, in the case of carbolic acid, only a solution of 1/10 for 5 minutes was effective for preventing growth of the *B. pestis*; in the case of mercuric perchloride only 20 minutes' immersion in a 1/500 or 30 M. in 1/1000 and 1/2000 was reliable; in the case of lysol (many brands used) 20 minutes' immersion in 1/50 solution was necessary. Alcohol (90 per

cent.) or undiluted spirit easily sterilised the sputum in three minutes; when diluted it was of no use. Both slaked lime and lime water were effective in 30 minutes. The other chemicals, including some much advertised specimens, appeared ineffective.

The viscosity of the sputum should, however, be taken into consideration when drawing any conclusion, but it may be wise for sanitary departments to ponder over these findings before launching into big purchases of so-called disinfectants for the control of plague epidemics.

Experiments upon tarabagans. Having failed to observe the existence of plague among marmots in the natural state, our next step was to ascertain how far such animals were susceptible to *B. pestis* under laboratory conditions. Like all rodents the marmot, when inoculated subcutaneously or intraperitoneally with *B. pestis*, developed Septicemic Plague as has been shown by Strong, Kitasato and myself. But I was anxious to observe the results of inhalation of the plague bacillus upon the animal. Dr Strong conducted one such experiment at Mukden in 1911 upon two large tarabagans, and although both died, only one showed undoubted signs of primary lung infection. In 1916 Eberson and I continued these inhalation experiments upon the small marmot (*Spermophilus citillus*) found in large numbers around the graveyards of Mukden. A number of these animals received inhalation of *B. pestis* ejected from a fine spray and were then thrown among others serving as contacts. The results were as follows[1]:

First series.	Marmots inoculated	12	Deaths	8
	Contacts	10	,,	3
		Total 22		Total 11
Second series.	Marmots inoculated	7	Deaths	5
	Contacts	9	,,	7
		Total 16		Total 12

We could therefore reproduce conditions among small marmots similar to those observed among men, although the percentage of deaths among the animals (68·4 per cent. of inhaled ones and 52·6 of contacts) might be higher than among human beings during epidemics.

In August 1921 we commenced a series of experiments in Harbin upon the Mongolian marmot or tarabagan (*Arctomys bobac*) with a view to finding not only the susceptibility of this animal to plague pneumonia but also the existence, if any, of chronic or subacute plague among the species.

Experiment B. One tarabagan (*T* 1) was firmly strapped upon the prepared stage with the nose held inside an iron muzzle. It was then covered with an oblong metal box open at the bottom and having a small circular aperture at the head end for the introduction of the nozzle of a spray.

A 48-hour-old agar slant culture of a virulent strain of *B. pestis* from the 1921 epidemic was suspended in 10 c.c. of salt solution and sprayed from a

[1] *American Journ. of Infect. Dis.* xx, No. 2, 1916.

graduated cylinder fitted with a very fine nozzle. The technique is the same as in the Mukden experiments[1].

The same experiment was repeated upon *T* 4, *T* 7 and *T* 10. Each animal so inoculated was kept in a cage measuring 2 by 2 by 2 ft. with two healthy ones. Two cages had flea proof iron gauze partitions to prevent the possibility of flea complication. The operators took all anti-plague precautions.

Experiment C. When tarabagans 1, 4 and 10 died, eight healthy animals were introduced among the contacts, two into each cage, so that for the two experiments 20 animals were employed altogether. Rabbit controls *R* 1, *R* 4, *R* 7 and *R* 10 were in every case used.

Experiment D. The same experiment as *B* was repeated with six tarabagans (*T* 31–36) two receiving direct inhalation from cultures obtained from dead *T* 1 and *T* 10 and the other four serving as contacts. All were placed in one cage 2½ by 2 by 2 ft. with no wire partition.

Results. All the six control rabbits died (*R* 1 in 36, *R* 4 in 40, *R* 7 in 50, *R* 10 in 50, *R* 31 in 130 (*i.e.* 5½ days) and *R* 32 in 154 hours (*i.e.* 6½ days)). Of the marmots, *T* 4 died in 4½ days showing at post mortem much inflammation of epiglottis and trachea, marked haemorrhages in left lung, peritoneum and intestines. *T* 10 died in 5½ days showing at post mortem blood-stained froth from nose and mouth (like man), congestion of trachea and bronchi with much pink sputum and distinct haemorrhagic spots not unlike pneumonia in the lungs. *T* 1 died 7½ days after inhalation and showed swollen dark cervical and bronchial glands, hyperaemic trachea and bronchi with pink sputum, and red patches of pneumonia in both lungs. *T* 7 remained alive until the 17th day when it was killed with chloroform after 20 minutes' struggle. At post mortem it showed swollen dark cervical glands, slightly congested trachea with semi-purulent contents, many yellow patches in lung substance which on section proved to be abscesses. In the spleen too an abscess was observed at the anterior horn. The first three animals evidently died of plague pneumonia, while the fourth developed a subacute form of plague which did not seem to inconvenience it. Numerous plague bacilli were found in all animals except *T* 7, where only a few scattered ones were seen in the heart blood, peripheral blood, lung tissue and cervical glands.

One contact which had been with *T* 10 was also killed on the 17th day and showed no apparent lesions in the organs, but some plague bacilli were detected in the heart blood (subsequently confirmed by cultures).

Both animals receiving inhalation in Exp. *D* died—*T* 31 in 5½ days and *T* 32 in 6½ days—and showed at necropsy changes similar to the others receiving inhalation[2].

[1] *American Journ. of Infect. Dis.* xx, No. 2, 1916.

[2] Since the above was written, more contact animals have been examined and plague bacilli have been found in the blood. One Tarabagan *T* 12 which was placed in the same cage as *T* 10 died spontaneously on Sept. 12 (*i.e.* 37 days afterwards) showing at post mortem congestion of trachea and lungs and abscesses in pharynx and spleen, all with positive findings in the smears and cultures.

The occurrence of plague bacilli, although few in number, in the blood of the two living tarabagans is of supreme importance, because it may explain the secret of the strange infections which have taken place in Siberia among Russians developing plague after skinning and eating apparently healthy animals. There are now under observation at Harbin still 19 tarabagans which have been in contact with lung infected animals and their progress will be watched with interest.

Post mortem records. Besides those at Hailar and Dalainor, we conducted 41 complete autopsies at Harbin, 34 of which were upon plague subjects, during the period 27th Feb.–21st May. Our findings will be published in a separate paper, but it may be interesting to note here that in the first part of the epidemic (before 27th April) all cases except those of three babies were pneumonic. On that date one septicaemic case was recorded, while during the two ensuing weeks all three autopsies revealed primary lung lesions. After 13th May every one of the ten performed was septicaemic except in a man who had a small patch of Broncho-pneumonia. From these pathological and our former clinical observations, it appears to us that the preponderance of the septicaemic cases in the later course of the epidemic exercised a marked influence upon its termination. If so, how was it effected? Could it be that the organisms passing through pneumonic cases were becoming so virulent that there was little or no time for the patients to develope pulmonary symptoms, and the medium of infection, namely the sputum, was therefore absent? As a consequence the later victims became less infective though invaded by more virulent bacilli, fewer infections took place and the epidemic gradually subsided. The alternative, namely a diminished virulence of the organism on account of the warmer weather, has little scientific evidence to support it; in our experiments conducted this summer the original strains grown in the winter seem to be as virulent as ever.

Treatment and protective inoculation. The treatment of Pneumonic Plague, in this as in previous epidemics, proved exceedingly unsatisfactory and no authentic case is on record where any serum or medicine has saved life. In our hospitals, anti-pest serum, neo-salvarsan, eusol, formalin, sodium gynocardate, and methylene blue were tried but found of no avail. No remedy has so far been found sufficiently powerful to stop the rapid distribution of the bacilli through the lungs and blood.

While engaged upon the experiments dealing with the action of disinfectants upon sputum, we noticed on frequent occasions that when the cultures were contaminated with a spore-bearing bacillus plague organisms did not grow. This accident put into our heads the possibility of using the spore-bearing organism for protective inoculation, therefore it was isolated. It was found to be non-pathogenic and similar to the potato bacillus, and three guinea-pigs were inoculated with emulsions of pure cultures. In the stress of the moment, whole agar slants of virulent plague bacilli were then injected into the peritoneum of each of these guinea-pigs. The first guinea-pig died

in $2\frac{1}{2}$ days, the second in 5 days and the third in 6 days, whereas under ordinary circumstances such large doses would prove lethal in 18–24 hours. The autopsy revealed in every case a localised peritoneal abscess with matting of liver, spleen, omentum and intestines, as if a strong local reaction had taken place. Under the microscope the pus showed both spore-bearing bacilli and numerous *B. pestis*, but the heart blood only a few or none at all. Encouraged by these results, we injected an emulsion of agar cultures of the spore-bearing bacillus as well as a *subtilis*-like organism (grown in big flasks) into two plague patients respectively, but with no apparent effect. It is possible that the conditions under which we were at that time working were not favourable, as our men were continuously threatened by the ignorant populace with personal violence and our hospital with fire. A well-fitted glass-lined ward with a separate compartment for the operator to perform intravenous injection might have been more satisfactory than the close poorly-heated rooms where hundreds of patients had previously died.

While the above attempts are far from complete, we shall continue them with a view to discovering a virus, which while deadly to the parasite is harmless to the host, a process which has already been successful in combating plant parasites, and in the extermination of plague-bearing rodents by the employment of rat-typhoid virus.

As is generally known to bacteriologists, *B. pestis* belongs morphologically to the "haemorrhagic septicemia" group of bacteria, whose other members produce highly fatal infective diseases among lower animals. To this class of disorders belong especially the affections known as swine-plague, fowl-cholera, rabbit septicaemia and rinderseuche. The bacilli are short, non-motile, non-spore forming, gram-negative, with a tendency to bipolar staining. While the organisms of fowl cholera and swine plague are extremely fatal to their respective hosts, they are apparently harmless to man. *Vice versâ*, *B. pestis*, so virulent to man, is absolutely innocuous to chickens, ducks and pigs, as we have again confirmed by injecting even 5 c.c. of human plague blood into a series of these animals with negative results. Is it possible that our future hope of protection against Pneumonic Plague, after the failure of autogenous vaccines and serum prepared after Haffkine's and similar methods, lies in these other organisms of the same family? Or, in view of the apparent rarity of tubercular lesions found in plague cadavers, shall we look to *B. tuberculosis* and its associates for a solution? The problem offers a wide field for research with ultimate benefit to mankind.

SUMMARY.

1. Pneumonic Plague epidemics arise as a secondary manifestation of Bubonic Plague.

2. The prevalence of purely septicaemic cases towards the end of the epidemic is significant as a probable explanation of its decline and termination.

3. Subacute or chronic plague may exist among tarabagans (*Arctomys bobac*) in Mongolia and Siberia, giving rise to periodical outbreaks of bubonic plague in man, as a result of direct infection from injury due to skinning by trappers or marmot eaters.

4. The tarabagan is easily susceptible to pneumonic plague produced by inhalation of *B. pestis* in spray form.

5. The existence of Pneumonic Plague carriers has been proved in the 1921 Manchurian epidemic.

6. Rooms where patients have died of Pneumonic Plague are not particularly dangerous. In all four instances recorded, sick patients travelling in railway carriages have not infected their fellow passengers.

7. Disinfectants and antiseptics, even in strengths above those usually employed, have very little effect upon plague sputum. Alcohol is the surest means of sterilising the hands and gloves in plague work.

8. We have cultivated *B. pestis* from seemingly dry sputum of patients.

9. The mask is the principal means of personal protection against Pneumonic Plague.

10. The problem of successful vaccination against Pneumonic Plague still awaits solution.