

ANTI-PLAGUE MEASURES IN SAN FRANCISCO, CALIFORNIA, U.S.A.

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Commanding Plague Suppressive Campaign.*

THE plague suppressive campaign which is now drawing to a close in San Francisco has been conducted almost entirely on the principle that the great factor in the spread and continuance of the disease is the rat. The fact that the epidemic among human beings ceased within four months after the beginning of active operations and that in spite of the distribution of the disease in almost every quarter of the city, only one hundred and fifty-nine cases, with seventy-seven deaths occurred, proves the wisdom of this policy. The campaign has been conducted by the United States Public Health and Marine Hospital Service.

The previous epidemic of plague existed from March, 1900, to February, 1904, although it is probable that cases occurred prior to the first date. It is thought that the disease was imported from Hong Kong. It was suspected among the Chinese as early as 1896 or 1898, but this was not proven at that time. In all probability it existed among the Chinese prior to 1900, but they were able to hide the few cases owing to the fact that they were treated by physicians of their own nationality. In 1900, when a white Inspector of the Dead was put on duty in Chinatown, the discovery of the disease was made.

The source of infection of the 1907 outbreak was in all probability a recrudescence from an old focus. During the previous epidemic cases were found outside the city of San Francisco, in Oakland and in Contra Costa County, across the Bay, and in 1906 a case was found in Oakland.

Plague in San Francisco

In all probability the infection in this instance was received from a ground squirrel (*Citellus beecheyi*), as there has undoubtedly been a ground squirrel enzootic of plague in Contra Costa County for several years. Four human cases occurred there in the previous epidemic and two during the summer of 1908. Infected ground squirrels and rats have been found in that section of country recently.

This was the second epidemic of bubonic plague in San Francisco, the previous outbreak having been confined to the Chinese quarter. The present epidemic began May 27, 1907, a little over a year after the great fire and earthquake, but no cases were discovered between that time and mid-August when the disease began to appear in various parts of the city. It should be noted that San Francisco has always had a great many fleas, but that during the summer and autumn of 1907 they were unusually prevalent, also that on account of the great catastrophe sanitary conditions were unusually bad in the city at that time.

The following tables show the incidence of human plague and the races attacked :

Epidemic Plague.

1907				Cases	Deaths
May	...	...	...	1	1
August	...	...	...	13	6
September	...	...	...	55	25
October	...	...	...	34	25
November	...	...	...	41	12
December	...	...	...	13	7
1908					
January	...	...	...	2	1
Total				159	77

Races attacked.

Americans	...	...	...	...	79
Europeans	...	...	...	...	66
Chinese	...	...	...	...	8
Japanese	...	...	...	...	5
African	...	...	...	...	1
					159

The last case of human plague occurred January 30, 1908.

The following table shows the number of human cases per month and the meteorological conditions during that time:

Month	Cases	Deaths	Average temperature	Rainfall in inches	Character of day
1907					
May	1	1	56·3° F.	·04	{ Clear 10 Part cloudy 17 Cloudy 4
June	0	0	57·2° F.	1·28	{ Clear 10 Part cloudy 14 Cloudy 6
July	0	0	58·0° F.	Trace	{ Clear 5 Part cloudy 17 Cloudy 9
August	13	6	59·3° F.	·02	{ Clear 11 Part cloudy 16 Cloudy 4
September	55	25	60·6° F.	·11	{ Clear 13 Part cloudy 15 Cloudy 2
October	34	25	60·6° F.	1·36	{ Clear 10 Part cloudy 10 Cloudy 11
November	41	12	57·8° F.	·04	{ Clear 14 Part cloudy 13 Cloudy 3
December	13	7	52·4° F.	3·66	{ Clear 6 Part cloudy 11 Cloudy 14
1908					
January	2	1	50·8° F.	4·88	{ Clear 5 Part cloudy 11 Cloudy 15

It will be noted that the greatest number of human cases occurred during the warm, dry months (August 1st to December 1st) i.e. during the period of greatest flea prevalence. Inasmuch as no effective work was done until September 25th and no great uniformity of action was secured until mid-November these figures may be taken as representing natural conditions.

The rats examined for September, 1907, were very largely collected from the infected districts, the remaining months give a truer picture of the condition of the entire rat population. It will be noted that while the incidence of human plague was greatest in the warm, dry months, rat plague was greatest in the cold, wet months. It is believed that this is explained by the fact that the rats congregate in their burrows to avoid the cold and wet and that their close proximity permits one infected rodent to distribute *Bacillus pestis*-laden fleas to all the other inhabitants of the warren.

Plague in San Francisco

The following table shows the incidence of rodent plague and its relation to meteorological conditions:

Month	Number examined	Number infected	Per cent.	Average Temperature	Rainfall in inches	Character of day
1907						
September	1002	27	2·69	60·6° F.	·11	{ Clear 13 Part cloudy 15 Cloudy 2
October	2679	23	·86	60·6° F.	1·36	{ Clear 10 Part cloudy 10 Cloudy 11
November	3954	36	·88	57·8° F.	·04	{ Clear 14 Part cloudy 13 Cloudy 3
December	4308	48	1·11	52·4° F.	3·66	{ Clear 6 Part cloudy 11 Cloudy 14
1908						
January	6622	70	1·05	50·8° F.	4·88	{ Clear 5 Part cloudy 11 Cloudy 15
February	11700	45	·38	51·0° F.	5·39	{ Clear 11 Part cloudy 12 Cloudy 6
March	19263	52	·26	54·8° F.	·90	{ Clear 20 Part cloudy 10 Cloudy 1
April	15524	34	·21	56·3° F.	·22	{ Clear 17 Part cloudy 10 Cloudy 3
May	11311	20	·13	55·4° F.	·76	{ Clear 17 Part cloudy 12 Cloudy 2
June	13624	4	·02	55·3° F.	·01	{ Clear 16 Part cloudy 9 Cloudy 5
July	11204	2	·017	57·4° F.	·02	{ Clear 11 Part cloudy 17 Cloudy 3
August	10988	0	0	57·3° F.	·01	{ Clear 11 Part cloudy 10 Cloudy 10
September	15902	0	0	59·3° F.	·29	{ Clear 16 Part cloudy 9 Cloudy 5
October	10178	2	·019	58·8° F.	·061	{ Clear 16 Part cloudy 7 Cloudy 8

All rodents captured or found dead were identified as to sex and species and were carefully tagged to show where, when and by whom captured. The following table shows the result of these identifications:

Total No. rats identified ¹	...	...	189016
<i>Mus norvegicus</i> (= <i>decumanus</i>)	...	...	152760
<i>Mus rattus</i> ...	...	...	3291
<i>Mus musculus</i>	...	...	32941
<i>Mus alexandrinus</i>	...	...	24
No. examined bacteriologically	...	...	138259
No. infected with <i>B. pestis</i>	...	...	368

Rats taken alive were chloroformed and combed for fleas. The fleas from each individual rat were placed in a separate vial containing 70% alcohol. These were delivered to the laboratory where they were identified by an entomologist. Of 10,972 rat fleas examined the following species were identified:

<i>Ceratophyllus fasciatus</i> ²	...	...	68.07 %
<i>Pulex cheopis</i>	...	...	21.36
<i>Pulex irritans</i>	...	...	5.57
<i>Ctenopsyllus musculi</i>	...	...	4.48
<i>Ctenocephalus canis</i>	...	...	.52

The *Ceratophyllus fasciatus* is the common rat-flea at all seasons on this coast. In one of the twelve sanitary districts of the city, however, the *Pulex cheopis* was most abundant from January to June as follows:

Of 1,153 determinations there were,

<i>Pulex cheopis</i>	...	...	---	67.82 %
<i>Ceratophyllus fasciatus</i>	...	...	...	30.78
<i>Pulex irritans</i>	...	...	...	.78
<i>Ctenocephalus canis</i>	...	...	...	.26
<i>Ctenopsyllus musculi</i>	...	...	...	.35

Plague foci were recorded in this district as follows:

Epidemic	...	...	---	4
Epizootic	...	...	...	38
No. of blocks infected as shown by human and rodent cases	...	...	...	21
Total rat catch from November 9th to June 30th				15,114

¹ To November 1, 1908.

² Specimens of these fleas were kindly sent to Cambridge by Dr Rupert Blue and were submitted to the Hon. N. Charles Rothschild who confirmed the determinations.—G.H.F.N.

Rats trapped in insanitary basements and stables had the greatest number of parasites. Sickly and very young rats showed a high degree of infestation. Sewer rats, as a rule, had few fleas. In the winter, from January to May (the off-season of plague) there were few, if any, fleas found upon the rats examined. In a count of twenty selected at random, not a single specimen was obtained. In Oakland, as late as June 15th, the same conditions were noted. On the 15th one hundred and eighty-seven rats (*Mus decumanus*) were chloroformed and combed, one hundred and forty-five rats were infested with five hundred and ninety-nine fleas and forty-two rats had no fleas. Ovulation was first noted in May.

Fleas from Human Hosts.

	Male	Female	Total
<i>Pulex irritans</i>	500	764	1264
<i>Ceratophyllus fasciatus</i>	—	4	4
<i>Ctenocephalus canis</i>	2	1	3
	<hr/>		1271

Of the 1271 fleas taken from the human host in San Francisco not one was a *cheopis* and only four were *Ceratophyllus fasciatus*. The hosts were the labourers engaged in the plague suppressive measures.

Although there were employed at one time over one thousand men, most of whom were in very close contact with rats, constantly entering buildings from which cases of human plague had been taken, no case of plague occurred among them. One morgue attendant, however, was stricken with the disease, probably by receiving infected fleas from the corpse he was removing. A physician and a nurse contracted the disease while in the discharge of their duty in the City and County Hospital. Bubo-septicaemic plague was admitted to the general wards of the hospital by mistake, no precautions being taken before the seizure of the doctor and nurse occurred. Both recovered. Precautions taken by the men consisted in wearing heavy clothing with high shoes, the trousers being tied to the leg by means of pieces of string. Almost all of the men wore oiled-leather gloves with gauntlets. When handling rats which had not been immersed in corrosive sublimate rubber gloves were worn or the rats handled with tongs.

In the laboratory great care was taken to prevent the rat-skinners from becoming infected. All rats were immersed in a corrosive sublimate solution before tacking them on the shingles, and rubber gloves worn by the rat-skinners. Rats were forwarded in heavy

galvanised iron cans having tight fitting covers, and were stretched on shingles. The tag was read and recorded in a book and the rat passed to specially trained skimmers who grew very expert in recognizing the macroscopic lesions of plague. They laid aside those which they considered most suspicious. All rats were carefully gone over by a bacteriologist and pathologist, special attention being paid to those set aside by the laboratory attendants. In the event of finding lesions which resembled plague, smears, cultures and inoculations into guinea-pigs were made.

In addition to plague many interesting pathological lesions were found. Among the animal parasites observed the *Trichinella spiralis* and the *Hymenolepis diminuta* are also parasitic for man. The *Trypanosoma lewisi*, *Trichosomum crassicaudium*, *Hymenolepis nana* were also observed. Scabies was noted as a very common condition. Among the organic lesions encountered may be mentioned dilatation of the pericardium, caseating abscesses of the lungs, hob-nail liver, nephritis, vesical calculi and tumor growths such as lipomata, fibromata, adenomata, sarcomata and carcinomata. Eighty cases of the leprosy-like disease of rats were found. There seems to be some connection between this disease and places where cattle are slaughtered or meat sold, but it has been impossible to decide how great a factor the meat industry may be in this disease.

The means by which the *Bacillus pestis* maintains its existence in quiescent periods has had considerable attention during the present epidemic and the conclusion has been reached that it is through a chain of acute enzootic foci in sewers and other inaccessible places. Inasmuch as no case of chronic plague, as described by the British Commission in India, was found out of 138,259 rats examined, it is not thought that chronic plague plays any great part in the continuance of the disease in San Francisco. This may possibly be explained by the fact that there seems to be some difference in virulence between the strain of *Bacillus pestis* found here and that recovered in Bombay. It has been observed that the present San Francisco strain does not lose its virulence on artificial media, but it has been the observation of many who have worked with the Bombay strain that in a few months it becomes weakened. This may account for the occurrence of chronic plague in India and not in San Francisco. As further evidence of the continuance of the disease by acute plague may be cited the fact that on tearing up wooden flooring and similar harbouring places extensive rat catacombs have been found, in many cases containing large numbers of rodent

cadavers. These vary from fresh bodies to mummified carcasses, showing that the epizootic has ranged over a considerable time. In almost all such cases in which bacteriological examination was possible they were found to have died of plague. This would seem proof that plague epizootics were continued in inaccessible and undiscovered places.

Experiments were made to determine how long rats would live under unfavourable conditions such as would be found on the freight trains, ships and other common carriers leaving the Pacific Coast. Without water or food of any sort, the maximum duration of life was five days, three rats being used in the experiment. On a diet of dried grain (wheat) entirely without water, the experiment being made on three young rats, the maximum time before death was fifteen days, the minimum, eight days. On a diet of bread and meat, without water, three rats on which the experiment was made were alive on the thirtieth day.

The plague eradication measures may be briefly summarised as follows:

A simultaneous attack upon the habitation and food supply of the rat.

The destruction of rat burrows and nesting places.

The separation of the rat from his food supply by concreting and screening such places as stables, warehouses, markets, restaurants, etc.

The prevention of the entry of the rat into human habitations by the use of concrete or other impervious material on the ground area or by elevating the building so as to allow free access to the natural enemies of the rat beneath the same.

Disinfection of rat burrows by the use of strong antiseptic solutions and chloride of lime in places likely to furnish fleas.

Disinfection of buildings in which either human or rodent cases have occurred. This latter measure is not considered as important as rat extermination. All the human cases were isolated in a rat-proof compound.