

PLAGUE AMONG GROUND SQUIRRELS IN AMERICA.

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(Plates XII and XIII. 1 Map.)

THE United States has been fortunate in never having had any extensive epidemics of plague. With the exception of a few cases, not over a dozen, that are directly chargeable to the infection of the indigenous rodents (ground squirrels), the disease has been confined to the two largest and most important cities on the Pacific Coast, San Francisco and Seattle. In each city the disease has yielded promptly to vigorous sanitary measures carried out by the public health arm of the Federal Government. Under the political organization of the Government, direct control of measures for the suppression of a disease is taken by the central sanitary authority only when a request is made by the local authorities, but it has been the experience that local authorities are prompt to make requests for assistance whenever any serious epidemic appears.

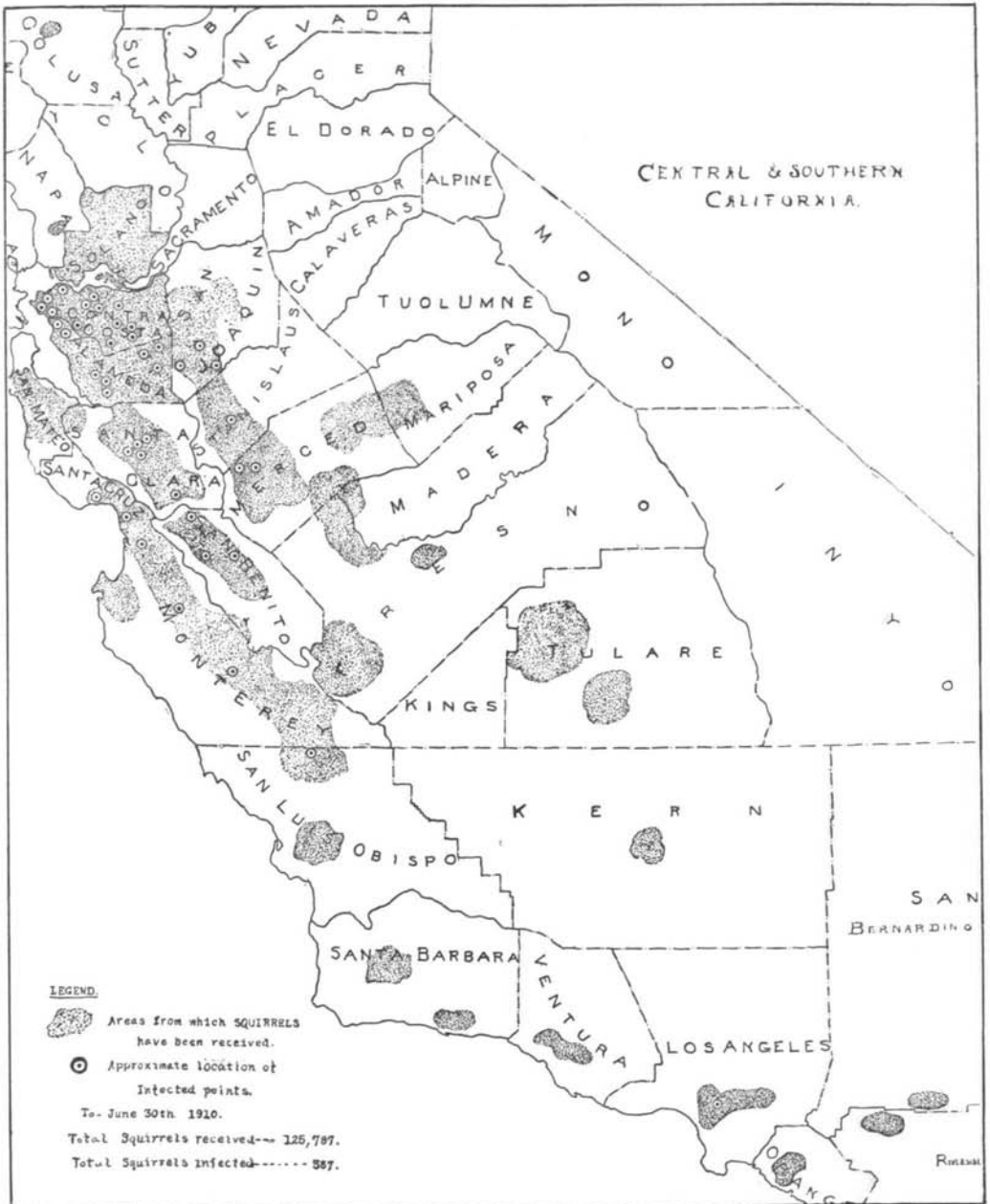
California, it will be recalled, is the State that forms the greater part of the Western Sea Coast of the United States. It lies between 32° 32' and 42° North Latitude, and 114° 30' and 124° 22' West Longitude. Its area is over 156,000 square miles. In size, the State is next to the largest in the Union, and perhaps excels all others in natural advantages, mineral and agricultural wealth, beauty and salubrity. San Francisco, the most important of the large cities, has a harbour equalled by few anywhere and excelled by none, and stands as a natural gateway to the Orient and to all Pacific ports. This port

enjoys an enormous commerce with all parts of the globe. With plague prevailing at a number of Oriental ports, it is scarcely a matter of surprise that even with an efficient maritime quarantine, the infection should have slipped in. There is no evidence that points to any particular vessel as the carrier by which the disease was imported, but it may be safely assumed that infected rats found their way from some vessel to the shore, or less likely, that infected foodstuffs imparted the disease directly to the shore rats.

Plague first appeared in the United States at San Francisco in 1900. There was no direct evidence that the rats were infected until several years later, but in view of what we now know of the relation of rat plague to human plague, we may assume that rodent plague was probably present at least as early as the first human cases. According to Surgeon Blue, U.S.P.H. and M.H.S.⁽¹⁾, the first suspicion of plague among the ground squirrels was aroused in 1903, when an epizootic

Table showing extent of investigation and cases of human plague.

County	Squirrels examined	Infected with plague	Ratio of infection	Human cases of plague of squirrel origin
Contra Costa	31857	245	1 : 130	6
Alameda	8985	85	1 : 105	3
San Mateo	2819	0	—	0
Santa Cruz	1590	3	1 : 530	0
Santa Clara	6813	23	1 : 296	1
San Benito	6239	24	1 : 259	1
Monterey	18855	4	1 : 4713	0
San Luis Obispo	10662	1	1 : 10662	0
San Joaquin	6884	9	1 : 764	0
Stanislaus	1976	5	1 : 395	0
Merced	10408	2	1 : 5204	0
Mariposa	687	0	—	0
Madera	785	0	—	0
Fresno	12726	0	—	0
Tulare	6367	0	—	0
Kern	326	0	—	0
Santa Barbara	4651	0	—	0
Ventura	2189	0	—	0
Los Angeles	10854	1 (1908)	1 : 10854	1
Orange	1792	0	—	0
San Bernardino	577	0	—	0
Riverside	1268	0	—	0
Solano	1070	0	—	0
Napa	114	0	—	0
Colusa	110	0	—	0
Total	150604	402	1 : 374	12



Map showing areas investigated and infected localities, prepared by Assistant Surgeon Friench Simpson, U.S.P.H. and M.H.S., by whose permission it is published. (San Francisco is on the peninsula just north of the county marked San Mateo. Oakland is in Alameda County, just across the Bay, east of San Francisco. Los Angeles is in the centre of the dotted area in Los Angeles County.)

affected so many of these rodents in Contra Costa County, California, that they were almost exterminated. Since that time there has evidently been a great increase among the rodents throughout this county. At about the same time, probably later (the history is not definite), there was a heavy mortality among the ground squirrels in Alameda County, which lies immediately south of Contra Costa County. There is no proof that the epizootic was plague, but as several cases of plague in man occurred in the territory invaded at about the same time, it seems not unlikely that this disease was present among the rodents. The victims were persons who had not been exposed to the possibility of being infected from a known epizootic among rats. This, coupled with the fact that several of these persons were known to have handled squirrels a few days before the onset of the symptoms, led to the suspicion that plague was prevalent among the rodents.

In the summer of 1908, two cases of plague (both fatal) occurred in the squirrel country. A short time after the occurrence of these cases, a dead squirrel was found near the house where one of the victims had lived. This squirrel was submitted to a bacteriological examination by Acting Assistant Surgeon William B. Wherry, U.S.P.H. and M.H.S.⁽¹⁾, and, as the result of his investigations, it was shown to be infected with plague. The case was studied independently by the writer⁽²⁾ with like result. Later in the same year, three other plague infected squirrels were found within a radius of a few miles of the first one.

The Ground Squirrel.

The California ground squirrel, *Citellus beecheyi*, is a burrowing animal that usually lives in colonies composed of from three or four to perhaps thirty members or more. The favourite locality for the burrows of these rodents is in the foothills or rolling country. They generally avoid land that is flooded from time to time. They have been seen by the writer on mountains to an altitude of over 3000 feet, and there are reliable statements of their presence at even higher points. Their food is grain, fruit, nuts, green grass, leaves, and seeds of various sorts. They are very destructive to crops, and consequently farmers and fruit growers wage a continual warfare against them.

The rodents are very prolific. We have counted 133 fetuses in fifteen consecutive females. The young are born in March, April, and May. During the rutting season the sexual glands of the male grow

almost as large as the end joint of the thumb, while during the remainder of the year these organs are scarcely larger than a pea.

The average weight of the adult rodents is about 750 grams; one of the largest we have seen weighed 1050 grams. The greatest length from tip of nose to tip of tail was 51 cm.; the majority are between 40 cm. and 45 cm. in length.

Before the traffic in these animals was prohibited by law they were to be found regularly in the markets in at least some of the large cities of the Pacific Coast. Even now they constitute a staple article of diet on the tables of many who cannot afford butchers meat, and are occasionally eaten by others.

Parasites.

Fleas: Ground squirrels are usually found to be heavily infested with fleas, the commonest species being *Ceratophyllus acutus* Baker; less frequently, the *Hoplopsyllus anomalus* Baker is found. We have shown that the former of these is capable of carrying plague among ground squirrels. No experiments have been performed with the latter. Both of these fleas readily attack man under experimental conditions and indeed also under natural conditions. At one time our squirrel stock room became so heavily infested that upon going into the room one was certain to be bitten by many of the parasites. It finally became necessary to use a pulicide upon the floor in order to make it possible to enter the room without having to suffer the attacks of the insects.

Lice, mites, and ticks are also found, the latter apparently only in certain seasons, and possibly only in limited areas. Our observations on this point are not completed. Of internal parasites, a cysticercus embedded in the muscles is occasionally encountered. Round worms and flat worms are not rare in the intestine.

Transmission of Plague.

The question of how plague is transmitted among squirrels and from them to rats and to man is one to which a positive answer cannot be given at present. Under the conditions of a laboratory experiment it is very easy to transmit plague from squirrels to guinea-pigs, to rats, and to squirrels by means of squirrel fleas, and it is not improbable that the conveyance in nature is in the same way.

It is impossible to say at present just what factors tend to limit the spread of the disease among the squirrels. It seems most likely that bodies of water and a thinning out of the squirrel population due to eradication or to unfavourable environment are probably efficient in setting boundaries to its extension.

Our work has now extended over a period of more than one year and there seems to be no reason for believing that there is any seasonal prevalence of plague among squirrels.

Extent of the infected area.

In the early part of 1909 steps were taken to determine the extent of the territory in which the squirrels were infected. The work was carried on by the U. S. Public Health and Marine-Hospital Service under the immediate direction of Surgeon Rupert Blue. The field work was assigned to Passed Assistant Surgeon W. C. Rucker, who was succeeded by Assistant Surgeon French Simpson, while the laboratory investigations were conducted by the writer. The plan in brief was to have the squirrels shot, packed in cans, and sent to one of the laboratories where they were submitted to a careful post-mortem examination for the purpose of detecting evidence of plague infection. In this manner, the work has been carried on over an area covering many thousand square miles. About 150,000 squirrels have been examined, and a small number of other animals, rabbits, field-mice, brush rats, etc. Up to September 1st, 1910, four hundred and two infected squirrels have been found, and one infected brush rat.

The infection has been found in ten counties in the State, and it is regarded as not improbable that in time others will be found to be infected.

One may obtain a better idea of the enormous volume of work necessary to complete the investigations when I state that in one case over 8000 squirrels were examined from one county (Monterey) before any infection was discovered. In other counties, infected animals were found in the first shipment sent to the laboratory.

The great bulk of this work has been carried on in the Federal Plague Laboratory at San Francisco, a smaller portion being done at the branch laboratories in Oakland and in Los Angeles. In the case of the latter, the work was entrusted to an assistant, not a physician, who had been thoroughly trained in the recognition of the gross lesions of plague in squirrels. When this man found lesions that he regarded

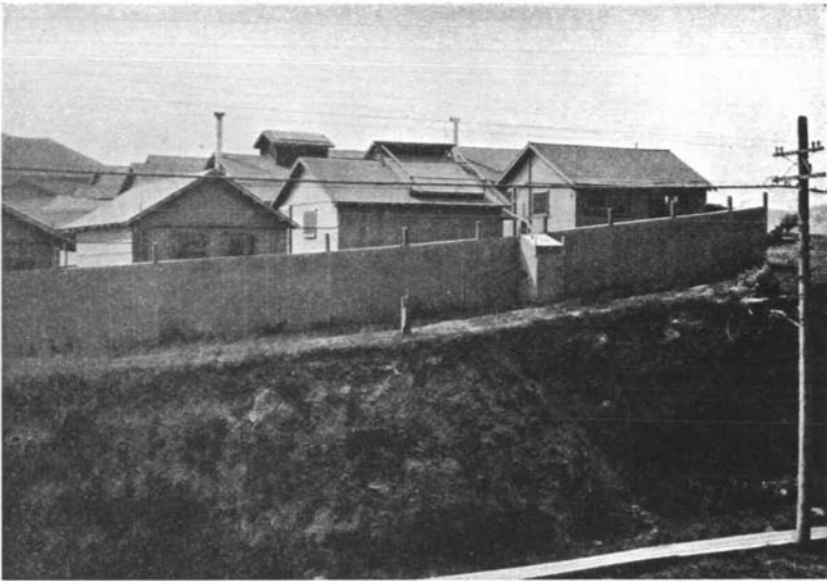


Fig. 1. Federal Plague Laboratory, San Francisco, California.

Buildings in foreground ; to extreme right, Bacteriological Laboratory, to extreme left, building for inoculated animals, in centre, rodent dissecting room.

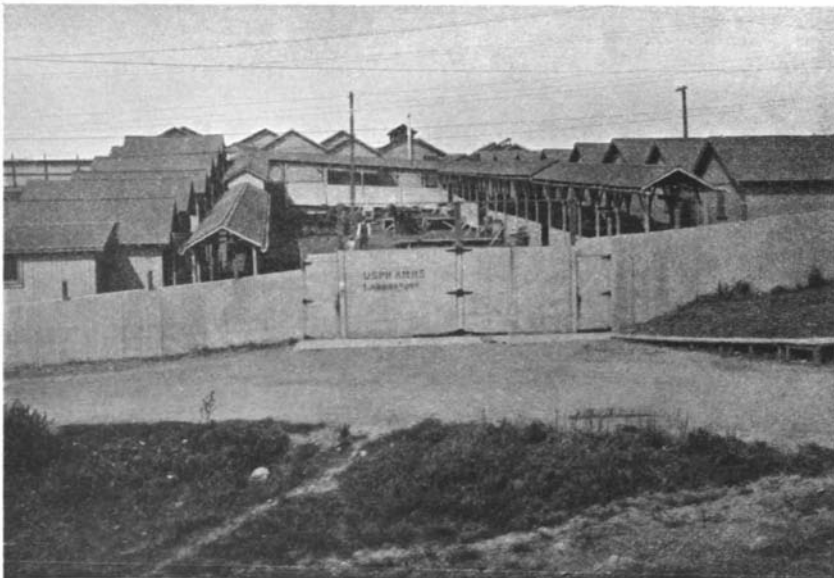


Fig. 2. Federal Plague Laboratory, San Francisco, California.

with suspicion, the suspected tissue was sent to the laboratory at San Francisco and there submitted to the usual inoculation tests. This plan was found to work very satisfactorily.

In the early part of the work, the diagnosis in the case of every infected squirrel was verified by a complete bacteriological examination; that is *B. pestis* was isolated and identified in pure culture. Later, on account of the large volume of work, it was found impracticable to do this and only those cases were bacteriologically verified that came from new localities, usually from a different farm. When 20 or 30 infected rodents were received from one ranch, obviously it would have served no particular purpose to have verified all of them bacteriologically. It is perhaps needless to remark that each squirrel received had been tagged to show the locality from which it came and that a careful system of checking was adopted in order that each infected rodent might be properly located.

Human Cases.

The cases of plague in man, with perhaps one exception which will be mentioned later, that have been traced to squirrel infection, presented no points of especial interest. The symptoms were not to be distinguished from those seen in plague originating from rat infection. The cases have all been of the bubonic type and there is this rather remarkable fact; with but two exceptions, in each of the nine cases of which the writer has personal knowledge, the primary bubo has been located in the axillary region. It seems probable that this is due to the fact that in plague of squirrel origin the infection is usually contracted from handling infected rodents, while in the case of plague derived from rat infection, it most frequently happens that the infection enters through the lower extremities, since these parts are more exposed to the bites of fleas.

The one case of especial interest to which reference has been made was reported in detail by Wherry and the writer⁽³⁾. The case began as an ordinary, fairly severe attack of plague. The acute symptoms however subsided and for a time it seemed probable that the patient would recover. Later he fell into a pyaemic state, and died on the 16th day of the disease. The post-mortem findings were unusual for plague. There were necrotic foci in the kidneys and in the liver, a large number of caseous nodules up to a walnut in size in the lungs, and multiple caseo-purulent lymph glands. In other words, the post-mortem appearances were those of subacute plague.

One other case seems worthy of mention. The facts were as follows:—

Late in the summer of 1908, a boy living in the city of Los Angeles was taken ill with symptoms of such a nature that the suspicions of the attending physician were aroused. The case followed the usual course of bubonic plague. The primary bubo was in the right axilla. A bacteriological examination of the fluid aspirated from this bubo showed a pure culture of an organism that gave all of the characteristic reactions of *B. pestis*. The case was a severe one, but the patient eventually recovered after a prolonged illness, during which several of the superficial glands suppurated.

No case of plague had ever been seen in this part of the State, and, so far as was known, there had never been any plague among the rodents of the city or its surroundings. The history however gave a clue to the origin of the infection. About five days before the boy became ill, he had picked up a ground squirrel for the amiable and charitable purpose of taking it to where it could get water to drink. The animal appeared sick, and it must have been very ill to have submitted to being captured by hand. The squirrel bit the boy on the right hand, and, as before stated, he became ill about five days later and developed a right axillary bubo. Whether the bite infected the boy, or whether ectoparasites from the squirrel got on him and infected him, we do not know. The squirrel escaped and its fate is unknown. While the boy was sick, a dead squirrel was found at a point within 100 yards of the place where the boy was when bitten. The squirrel was shown by bacteriological examination to be plague infected. Exterminative measures were undertaken, during which several thousand squirrels were killed and examined, but no case of squirrel plague was found beyond the one previously mentioned. The sick squirrel and the dead one were found a short distance from the switching yards of the railroad which connects Los Angeles with San Francisco. At the latter place a rather widespread epizootic of plague had prevailed among the rats a few months before. The most reasonable way to explain the squirrel infection in Los Angeles is by assuming that an infected rat was carried from San Francisco, and this rodent in some way caused a small outbreak among the squirrels in the territory adjacent to the railroad yards. This case has been related somewhat in detail as it was almost of the nature of a laboratory experiment. It is the only one in which there is a history of a bite by a squirrel.

Three other cases of plague in squirrel hunters have come under my

observation. All of these men shot and handled squirrels on farms on which infected squirrels were known to exist. In one case, symptoms appeared three days after contact with the squirrels; in the others, after an interval of five or six days.

Since the sanitary authorities have been in a position to ascertain the facts in relation to squirrels, no case of plague has occurred in the State, except those that have developed at points where ground squirrel plague existed.

All of the cases of plague in man have been submitted to careful bacteriological examination, and in each instance the plague bacillus has been recovered.

The question of the mortality among persons infected from ground squirrels may be answered as follows: Of the nine cases of which I have personal knowledge, five died. This number is of course too small to be used as a basis of comparison, but one is probably justified in saying that there is at least no striking difference between the mortality from plague of squirrel origin and that of rat origin. I shall in another place make mention of the virulence for laboratory animals of the bacillus isolated from infected squirrels, and from persons presumably infected from squirrels.

Lesions of Natural Plague in Ground Squirrels.

The lesions of plague in squirrels resemble more closely the changes found in plague in the guinea-pig than those present in rats and mice. They present a wider variation than those found in other animals. We may have nothing to excite suspicion beyond a small purulent focus in a lymph gland, but when this is submitted to the test of inoculation into a guinea-pig, the results show that plague infection is present. On the other hand, we may have very extensive necrotic changes not only in the majority of the superficial glands, but in the internal organs as well.

The lesions may be described briefly as follows⁽⁴⁾:

A *bubo* is present in about four-fifths of all cases. One or more glands may be affected. Those in the inguinal region are most frequently involved; next in frequency came those in the cervical region, and finally those in the axilla. The *bubo* is occasionally surrounded by a haemorrhagic area; usually it is not. There is sometimes a gelatinous infiltration in the surrounding tissue, but this is not common. In many cases, changes in the tissue around the gland

involved are almost entirely wanting. The contents are usually either blood stained, rather dry, and distinctly necrotic (caseous) or in the form of a yellowish tenacious semifluid mass (purulent). The former is probably but an earlier stage of the latter. Upon microscopical examination buboes that are distinctly caseous are generally found to be swarming with characteristic bacilli, while the purulent ones usually show no organisms at all, or none that bear any close resemblance to the pest bacillus.

The spleen. This organ is usually enlarged and frequently contains caseous or purulent foci.

The liver. Lesions are found less often in the liver than in the spleen, but when they do occur they are of the same nature as those seen in that organ.

Lungs. Lesions in the lungs are found rather frequently. They fall into two classes: first, a rather diffuse gray consolidation which may affect a whole lobe or a whole lung; second, disseminated purulent or caseous areas varying in size from a pea to a pin-head.

From our experience it would seem that one is justified in speaking of the following types of cases.

Acute cases. A bubo is practically always present. There is often some haemorrhage into the periglandular tissue. The gland structure is replaced by a reddish or salmon coloured, rather dryish, friable mass. The spleen is generally very much enlarged and is dark in colour. Pest-like bacilli are abundant.

Subacute cases. Here there are caseous or purulent lesions in one or more of the internal organs, liver, spleen and lungs. There is usually, but not invariably, a bubo. Pest-like bacilli may be numerous, but usually are scarce or absent.

Residual abscesses. A large number of cases are found in which there is only a purulent lymph gland or an enlarged gland showing a few purulent points. Pest-like bacilli are rarely found. These are looked upon as cases that are in process of recovery.

Bacteriology.

Smear preparations: In only about one-fourth of the cases will stained smears show the presence of a sufficient number of cocco-bacilli, characteristic in size and shape, to justify one in attaching much importance to them in making a diagnosis.

Cultures: From ground squirrels presenting lesions of the nature mentioned above, we have isolated an organism giving all of the cultural

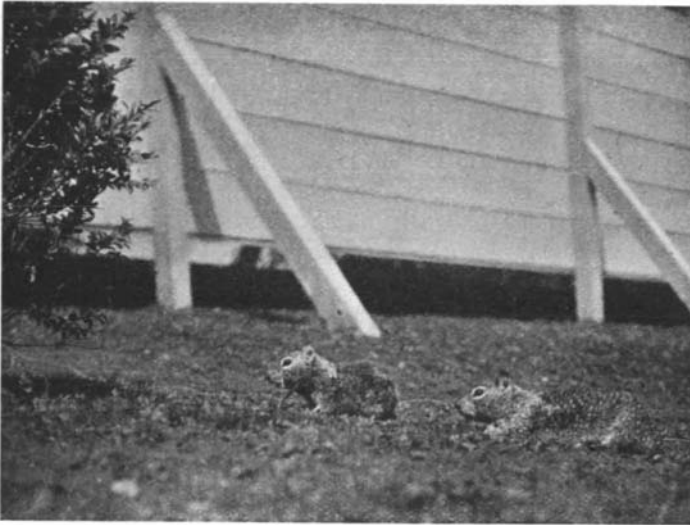


Fig. 1. Live Ground Squirrels (*Citellus beecheyi*).

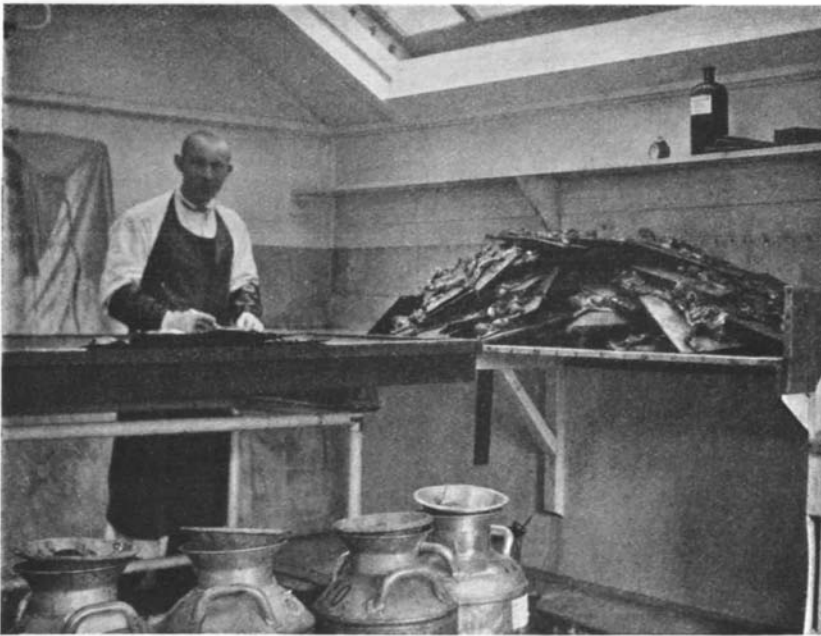


Fig. 2. Federal Plague Laboratory, San Francisco, California.

Laboratory assistant dissecting squirrels. Note cans in foreground. Squirrels are shipped to laboratory in these cans.

reactions of *B. pestis*. Study has failed to show that it is in any way different from the bacillus isolated from cases of plague in man or in rats. It is not considered necessary to go into the cultural reactions here, but I may say that the growth on agar is in the form of translucent, sticky, drop-like colonies; in broth, flocculi are formed, with a precipitate later. On salt agar, characteristic involution forms are developed.

Pathogenicity: The organism isolated is virulent for rats, mice, guinea-pigs, and rabbits, and produces the usual lesions of plague in these rodents. The virulence in some cases is as high as that of strains isolated from natural plague in rats and in man; in others, it is lower. White rats inoculated with small doses nearly always die on the third, fourth or fifth day, while guinea-pigs generally die on the fourth, fifth, sixth or seventh day, occasionally later.

We have tested the protective power of anti-pest serum against the bacillus isolated from squirrels, and from human cases believed to have been infected from squirrels. As a result of the experiments with the bacilli isolated from three human cases and from five squirrels, we have shown that the anti-pest serum (imported) invariably protects against the infection.

A Plague-like Disease of Squirrels.

In the search for plague among ground squirrels, a very interesting disease has been observed. It is characterized by a caseous bubo (sometimes haemorrhagic) and necrotic foci in the spleen and liver. The lesions would certainly lead one to suspect plague infection. Further, the resemblance to plague is heightened by the fact that guinea-pigs inoculated from these squirrels die between the fifth and eighth days with lesions that are remarkably like those of plague. The cause of the disease, however, is but feebly pathogenic for rats. This fact, together with negative results of stained smear preparations and of cultures, readily differentiates it from plague. No etiological agent has yet been discovered.

Significance of Plague among Squirrels.

This subject will be considered first in relation to the cases of plague in man that may be expected to arise from the presence of the disease among the squirrels. The experience in the past has been that the largest number of cases of plague attributed to squirrel infection in

one year was three. This makes it evident that there is no special cause for alarm on this ground. It is of course quite possible that cases have escaped observation, or have inadvertently been reported under another diagnosis.

As was pointed out two years ago by Wherry⁽¹⁾, and as I have had ample opportunity to observe myself, rats and squirrels may live in close association. Recently, Converse⁽⁵⁾ has reported the presence of ground squirrels and rats in the same burrows in the suburbs of San Francisco. It would seem that an important problem of the squirrel plague situation is the prevention of the infection of the rats in the cities of the country.

Another danger is the infection of other rodents in or contiguous to the area of squirrel plague infection. We have found one infected brush-rat (*Neotoma*) and it is possible that in time other wild rodents will be found to be infected.

Whether the epizootic among the squirrels will die out in time is a question that no one can answer at present. It is worth noting that in certain of the counties that are known to be infected, many of the healthy squirrels are quite resistant to laboratory inoculation with *B. pestis*, while the squirrels from localities in which no infection has been found are almost uniformly susceptible to infection.

Extermination of Squirrels.

Farmers have long carried on a warfare against ground squirrels on account of the damage the rodents do to crops. The usual procedure is to poison the animals with strychnine, or some other toxic agent that is administered on grain; another method is to treat the burrows with bisulphide of carbon. Both methods are efficient, and each one has a definite sphere of usefulness; the former in dry weather, the latter during the wet season when the moist ground will "hold the gas."

Eradication on a large scale. The Legislature of the State of California has passed a law requiring land holders to exterminate squirrels and other rodents on their premises and providing a penalty for failure to do so. Plans are being matured for enforcing this law, and it is believed that within two or three years the rodents may be eradicated or at least so reduced in number as to cause the extinction of plague among them.

Squirrel extermination for protection of cities. As there seemed to be some probability that the rats in the cities of Oakland and Berkeley adjacent to the squirrel infested territory might become

infected, a campaign having for its object the extermination of the squirrels in the territory immediately surrounding these cities was inaugurated by the writer. The work has been reasonably successful. It was found that while it was simple enough to poison all or practically all of the squirrels in the territory, there would be an influx from the periphery to take the place of those that had been destroyed. An interesting point that developed in connection with this work was the discovery of a large focus of infection within less than a mile of the city of Berkeley.

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