TREASURY DEPARTMENT

Public Health and Marine-Hospital Service of the United States

THE RAT AND ITS RELATION TO THE PUBLIC HEALTH

BY VARIOUS AUTHORS

PREPARED BY DIRECTION OF THE SURGEON-GENERAL

WASHINGTON
GOVERNMENT PRINTING OFFICE
1910

TABLE OF CONTENTS.

Page.

LIST OF ILLUSTRATIONS.

THE RAT AND ITS RELATION TO THE PUBLIC HEALTH.

By Walter Wyman,
Surgeon-General of the Public Health and Marine-Hospital Service.

INTRODUCTION.

The science of bacteriology has elucidated many facts with respect to the causation of disease, and with this advance in knowledge, old theories regarding the miasmatic and humoral origin of human ills have been abandoned.

Epidemiological studies have likewise determined the methods of transmission of many of the infectious and contagious diseases, thus eliminating erroneous conceptions that they are attributable to some mysterious condition of the atmosphere or soil, or to a visitation of the wrath of the Almighty.

Both these sciences have contributed to our knowledge of the relationship of living things, particularly with respect to their influence upon each other in relation to health and disease. It is now known, for instance, that mosquitoes are the pests of man, not only because of their bites, but because they at times transmit malaria, dengue, filariasis, and yellow fever. So, too, it is known that rodents are the enemies of man, not only because of the toll exacted from him, but because they are the principal agents in the propagation and spread of bubonic plague.

Ancient writings abound in allusions to pestilences and their connection with epizootics among rats and mice.

In the Book of Samuel there is reference to a pestilence having relation to mice, and that it might be stayed the Philistines made offerings of golden images of the mice that marred the land.

During the centuries that have intervened rats have migrated to practically every quarter of the earth, causing untold losses on account of their depredations. They have also, in all probability, been the primary agents of transmission in the pandemics of plague which have visited the earth. The fact that plague is due to a specific microorganism, and that its presence in man is also associated with epizootics in rats, has led to a more careful study of this animal, particularly in relation to his habits, the diseases from which he suffers, and the methods necessary to his control. Prior to the beginning of the present pandemic of plague which had its origin in China, interest in the rat was almost wholly an economic and financial one. Since that time evidence has been rapidly accumulating which proves that this animal and his parasites are responsible for the transmission of plague and that plague itself is essentially a disease of the rat.

A knowledge of this animal on the part of the sanitarian therefore becomes essential. During the enforcement of antiplague measures in California, Hawaii, the Philippine Islands and elsewhere, observations of great value have been made and their practical application has resulted in better directed efforts for the elimination of the disease.

In studies of plague and leprosy with the view to their diagnosis and control, it is not enough now to isolate the microorganisms responsible for these diseases, but the sanitarian must be able to recognize the pathological conditions present in animals affected, and to do so he must have practical knowledge of this subject in order that he may differentiate between the various diseases from which these animals suffer.

Opportunity for observation and study of the diseases of rats and the methods necessary to their eradication has been afforded to the officers of the Public Health and Marine-Hospital Service who are constantly stationed on the outposts in the warfare against exotic diseases. The results of these observations have been utilized by officers of the service, and some of them have been published for the benefit of others.

The rat has received much attention of late in other parts of the world. In Denmark, for instance, a legalized warfare against rodents has been begun, principally on account of their influence in the transmission of trichinosis. In England there exists The Incorporated Society for the Destruction of Vermin, and in other places rat destruction is being agitated both from economic and public health standpoints.

In view of the great importance of the rat in relation to the public health, it has been thought advisable to collect and publish all pertinent information on the subject, in order that public health officials who should be on the lookout for the appearance of plague among rodents might have available a reliable treatise on the subject.

Studies of rodents from a biologic and economic standpoint come within the province of other departments of the public service, and the cooperation of the Biological Survey and Bureau of Entomology of the Department of Agriculture was therefore requested and received.

The subjects dealt with in this publication have been prepared by those having wide experience.

In the chapter on natural history by Mr. David E. Lantz there is given a classification of rats as well as the distribution of the genus *Mus* in America. An interesting and important fact is mentioned that the Biological Survey has no records of the presence of the brown rat in Nevada, Utah, Wyoming, Idaho, and the greater part of Montana. Mr. Lantz also describes the different species in America, and refers to their habits as to breeding, feeding, migrations, invasions, and ferocity. The facts presented by him emphasize the great difficulty of ridding cities of these pests.

Passed Assistant Surgeon McCoy discusses plague infections in rats and describes the methods of examination. He also describes the gross lesions found in plague rats, gives the bacteriologic diagnosis of rat plague and the cultural characteristics of the plague bacillus on various media. He gives the methods of artificial infection of rats with plague, and reviews the recent work of Ledingham in relation to the histology of rat plague. Finally, he presents results of his own investigations to show that the wild rat is not especially susceptible to plague infection, and that a certain percentage of such animals enjoy a natural immunity to plague.

Doctor Brinckerhoff discusses rat leprosy; states that it is very similar to human leprosy, and that it is caused by a bacillus which closely resembles the bacillus of Hansen. He describes the pathological changes found, and expresses the hope that the disease will receive further earnest study, in order that additional information may throw light on the problems presented by leprosy in man.

Passed Assistant Surgeon Currie briefly outlines the bacterial diseases of the rat, other than plague and leprosy. He mentions the great utility that would follow the discovery of a rat destroying bacterium, but states that it appears now more than probable that few such natural diseases of rats exist.

In a chapter on organic diseases of the rat, Doctor McCoy summarizes the results of his observations made during examinations of these animals in the Federal laboratory of the service at San Francisco. These observations are of interest, and will assist those engaged in such work to further classify the pathological changes noted as well as differentiate them from plague.

The ecto parasites of the rat are classified and described by Mr. Nathan Banks, and he has presented in condensed form information of much practical value upon the subject.

Dr. Ch. Wardell Stiles discusses the internal parasites of rats and mice in relation to the diseases of man. He regards the rat as a permanent reservoir for trichinosis, and states that this disease will probably never be eradicated from man until rats and mice are practically eradicated, and a national campaign directed against trichinosis must take the rat into consideration.

A compendium of animal parasites reported for rats and mice is presented in a chapter by Ch. Wardell Stiles and Albert Hassall. While, as the authors state, no list of this kind can ever lay claim to being complete, it represents the present knowledge of the subject.

In a discussion of the flea and its relation to plague, Passed Assistant Surgeon Fox summarizes the theories as to the transmission of this disease. He also mentions the insects that have been suspected of transmitting plague and presents accumulated evidence that fleas actually convey the infection. He then gives the anatomy of the mouth parts of the *Ceratophyllus Fasciatus*, the common rat flea of North America. He also enumerates the fleas that have been found on rats, and gives the results of identifications of 19,768 fleas in San Francisco and Oakland, Cal. The plates accompanying this article, and their description should be of great value to those engaged in antiplague measures.

Surgeon Blue briefly discusses the subject of rodents in relation to the transmission of bubonic plague. He discusses the theories as to the cause of seasonal prevalence of this disease and presents a table showing the number of rats examined during the different months of the year, the number found infected, the average temperature and rainfall for those months and the character of the days, as to the number clear, partly cloudy, or cloudy. He refers to plague infection in ground squirrels in California and warns against the possibility that this animal may become responsible for the establishment of a permanent focus of plague on the Pacific coast of the United States, as the marmots are so concerned with regard to India.

The all-important subject of rodent extermination is considered in detail, various phases of the subject being dealt with by different authors.

Passed Assistant Surgeon Rucker discusses the destruction of these animals by trapping, poisoning, cutting off of food supply, and destroying of existing nests and at the same time preventing the making of new ones. He describes the methods of use of the various mineral poisons, but finally states that rodents must be builded out of existence; in other words, habitations must be rendered rat proof.

Mr. Lantz, in discussing the natural enemies of the rat, mentions the animals that destroy these pests. He concludes that on account of this function bounties for the destruction of small animals that prey on rodents can not be justified and that they should in the future be protected in every way possible.

Passed Assistant Surgeon Creel discusses rat proofing as an antiplague measure, and gives in detail the principles of construction necessary. He concludes that rat proofing is the most valuable antiplague measure, and that it should precede auxiliary measures such as trapping and placing of poisons.

Surgeon Rosenau discusses the bacterial viruses in relation to rat destruction. As a result of his investigations in the hygienic laboratory and the reports of investigations and practical use elsewhere, he concludes that the bacterial viruses have signally failed to accomplish the mission for which they were intended, and that they are not entirely harmless to man, as has been stated.

Passed Assistant Surgeon Heiser briefly outlines the measures recommended for the eradication of plague in cities by means of sectional extermination of rats and general rat proofing. He gives results following this method of procedure in Manila, and presents charts showing how to deal with infected city districts.

Passed Assistant Surgeon Hobdy, in a chapter on the rat in relation to shipping, refers to the voyage-making tendencies of the rodent, its destructiveness aboard ship, and its power of adapting itself to unusual conditions and surroundings. In one small lumber vessel fumigated by Doctor Hobdy at the Angel Island quarantine station there were collected 525 dead rats. Mention is also made of another vessel on which were collected 1,700 rats after fumigation. He discusses the methods by which it gains access to vessels, and outlines the practices that should be observed to keep it off. He also describes in some detail the measures to be adopted for its destruction after it has gotten aboard ship, and mentions the different methods of fumigation.

Mr. Lantz, in a third paper, discusses the rat as an economic factor, and states in his paper that they do not serve any useful purpose. On the other hand, they cause enormous loss through damage to grain, merchandise, poultry and eggs, game and wild birds, fruit and vegetables, and flowers and bulbs. They also cause damage by setting fire to buildings and destroying furniture. He refers to various estimates made of the losses in the United States from rats, and they vary from $35,000,000 to $50,000,000 a year; but at the same time he states that, with present information, any attempt to state the amount of loss from rats would be largely guesswork.

Assistant Surgeon-General Kerr refers to the rat as a factor in international sanitation, and briefly outlines the provisions contained in international sanitary agreements for their eradication. He reviews the efforts being made at the more important seaports to exterminate rats, as well as the methods being employed to that end. The information presented is, in part, compiled from consular reports received through the Department of State. There are given, so far as obtainable, copies of laws and ordinances enacted for the destruction of rats and the different methods practiced in ports where plague has prevailed, and the facts presented indicate that a more or less widespread crusade against rats is being carried on. He expresses the belief that it is too much to expect that the rat population can ever be exterminated from any city, but that it is not too much to expect that ocean carriers can be freed from rodents and kept so, which action would confine plague within continental boundaries.

Epidemiological studies made of plague since the adoption of the International Sanitary Convention of Paris and the International Sanitary Convention of Washington have proven that the rat and its parasite, the flea, are the agents of transmission of the disease. In other words, where rats go plague will go. I believe, therefore, that in order to stop the further progress of plague, radical measures should be adopted, and in a communication of February 26, 1909, addressed to the Secretary of State, I suggested the advisability of submitting the question of a systematic destruction of rodents aboard ship to an international sanitary conference, with the view to the adoption of an international sanitary regulation on the subject. The adoption of such a regulation would undoubtedly lessen quarantine restrictions, prevent the destruction of cargo by rodents, and obviate the danger of the further spread of plague.

Until ships are freed from rats, each country must take all necessary precautions, consistent with international agreements, to destroy rats; and the sanitary authorities of infected localities must, at great expense, determine the extent of infection among rodents, with the view to its elimination. This problem when it presents itself in a community is of great magnitude, and those responsible for its solution should be familiar with all its phases.

It is with the view to supplying the necessary information in one treatise that this publication is issued. In its preparation the bureau has had the cooperation of the Department of Agriculture and acknowledgements are due, and here made to, the officers of that department for their hearty cooperation in contributing some of the chapters which follow.

NATURAL HISTORY OF THE RAT.

By David E. Lantz.
Assistant, U. S. Biological Survey, Department of Agriculture.

INTRODUCTION.

The extermination of rats has become one of the serious problems of modern times. That such noxious animals should have flourished so long is not creditable to our civilization. While no kind of rat can be regarded as harmless, the various species differ greatly in harmfulness. In comparison with the cosmopolitan species that have reached our shores from the Old World, our native rats do little damage. It is important, therefore, to be able to recognize the introduced forms, to understand their habits, and to concentrate efforts for their extirpation.

CLASSIFICATION OF RATS.

Rats and mice belong to the *Rodentia*, an order which comprises more than a third of all living species of mammals. Also, it exceeds any other mammalian order in the number of its individuals.

Rodents are mainly herbivorous mammals, mostly of small size, having a furry, sometimes a spiny, integument, clawed digits, and usually plantigrade feet. The most important distinguishing character of the order is its dentition. This is marked by the absence of canine teeth and the presence of strongly developed incisors growing from permanent pulps. The incisors are never more than two in the lower jaw and usually but two in the upper. They are elongated, curved, chisel-like in shape, and continue to grow throughout the life of the animal. Only the front of these teeth is covered with enamel, a provision which keeps them sharp by the more rapid wearing away of the softer dentine in the body of the tooth, as the upper and lower pairs meet in gnawing. Between the incisors and the cheek, or molar, teeth of rodents there is a wide, vacant space, marking the entire absence of canines.

The most extensive family of rodents is the *Muridæ*, a name which applies to rats and mice in the widest sense of those terms. It is difficult to characterize the family, since it members differ widely. However, most of them are rat-like in form and light and active in movements. None of the family have premolars; and, except in a single genus (*Hydromys*), the number of molars is three. Oldfield Thomas, the eminent English zoologist, includes in this family no less than 77 genera, or almost half the total of 159 which he ascribes to the whole order *Rodentia*.[a] He further subdivides the *Muridæ* into a dozen subfamilies, of which the *Murinæ* and the *Sigmodontinæ* are the most extensive. The name *Cricetinæ* is now generally used instead of *Sigmodontinæ*, though not always with the same limitations.

The *Murinæ* comprise only Old World rats and mice, while the *Cricetinæ* are, in the main, American forms. In the *Murinæ* the cusps, or tubercles, of the unworn upper molars are arranged triserially, or in three longitudinal rows; in the *Cricetinæ* they are arranged biserially, one row on the outer and one on the inner margin (fig. 1). The wearing away of these cusps leaves characteristic curved lines of hard enamel surrounding areas of dentine. When the cusps are

Fig. 1a. Fig. 1b.

FIG. 1a.—Upper molars of the brown rat (*Mus*): tubercles in three rows.
FIG. 1b.—Upper molars of the rice rat (*Oryzomys*): turbercles in two rows.

in pairs the worn pattern looks somewhat like the Greek letter sigma (Σ), whence the name sigmodont, often applied to native American rats and mice.

The *Murinæ* are the true rats and mice, typified by the genus *Mus*, which contains by far the largest number of species. Trouessart, in his Catalogus Mammalium, enumerates 260 species of *Mus* described before 1905. Since that date a number of new forms have been described.

The genus *Mus* is characterized by narrow, ungrooved incisors; three small, rooted molars; soft fur mixed with hairs, sometimes with spines; a rudimentary pollex having a short nail instead of a claw; a long tail bearing rings of overlapping scales and often naked or nearly so. The ears are rather large, the eyes bright and prominent,

[a] Proc. Zool. Soc., pp. 1012–1028, 1896.

and the muzzle somewhat pointed. The members of the genus are natives of the Old World, throughout which, with the exception of Madagascar, they are quite generally distributed. Nearly seven-eighths of the whole number of species are commonly called rats.

The distinction between rats and mice is arbitrary and based on size. Exclusive of the tail, rats may be said to vary in length from 4½ to 10 inches or more, while mice measure from 2 to 4 inches. With few exceptions, rats have six well-defined footpads (plantar tubercles), the last on the hind foot being elongated in shape; the last hind-foot pad of mice is usually circular (fig. 2).

Of the many species of *Mus* only three or four have developed the ability to adapt themselves to such a variety of conditions as to become cosmopolitan. Four have found lodgment in America: The common house mouse (*Mus musculus*); the old English black rat (*Mus rattus*); the Egyptian, or roof, rat (*Mus alexandrinus*); and the brown rat (*Mus norvegicus*), known also as the gray rat, barn

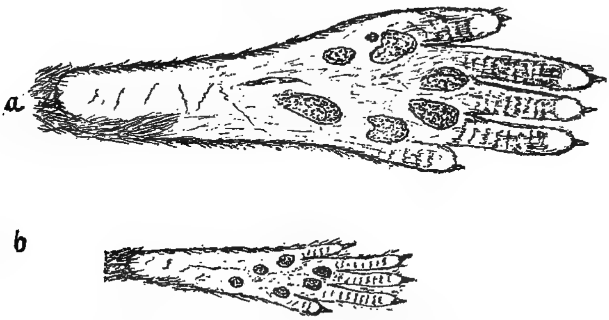


FIG. 2a.—Right hind foot of brown rat, showing long sixth foot pad.
FIG. 2b.—Right hind foot of house mouse, showing round sixth foot pad.

rat, wharf rat, sewer rat, and Norway rat. The black rat and the roof rat differ from each other chiefly in color. Indeed some zoologists regard them as races of the same species, and the trinomial *Mus rattus alexandrinus* for the roof rat is now in use among zoologists.

DISTRIBUTION OF THE GENUS MUS IN AMERICA.

The common house mouse (*M. musculus*) found its way to America soon after the first settlement by Europeans. It now inhabits all settled parts of North and South America, as well as nearly the entire Old World; but in very cold regions it does not always survive the winters, and is therefore comparatively scarce or local. It almost always reaches a new settlement sooner than the rat.

The black rat (*M. rattus*) has been known in Europe since the twelfth century. It was carried to South and Middle America about three and a half centuries ago (1554). The time of its arrival in the

English colonies of North America is not known with certainty, but it was well established in the settled parts by the beginning of the eighteenth century. Soon after the arrival of the brown rat, the black species began to decrease in numbers, and has become extinct in most localities. At present it is not uncommon in some parts of the South, and still occurs in scattered colonies in Canada and some of the States east of the Mississippi, and also on some of the coastal islands. It is occasional in many of our seaports, being apparently brought from the Far East in merchandise. Except in a few ports like San Francisco, where new arrivals are probably rather frequent, these introduced individuals are often destroyed before they multiply. The history of the black rat in Europe and its disappearance before the brown rat is an exact parallel to its history here, and the animal is now comparatively rare north of the Alps, except in the Channel Islands.

The Biological Survey has specimens of the black rat from Massachusetts, New Hampshire, Georgia, Florida, Alabama, California, and Washington, and also from Mexico, Honduras, Nicaragua, and Hawaii. There are authentic records of its recent occurrence in Newfoundland, Quebec, Nova Scotia, New York, North Carolina, Tennessee, West Virginia, and Mississippi. In parts of South and Middle America it is abundant.

The roof or Alexandrian rat (*M. alexandrinus*) is similar to the black rat in form and general habits, though not in color. Little is known of its history, but it is thought to be a native of Egypt, where it is still abundant. It has established itself in many parts of the world, mainly in warm climates, and is common near the coast in the southern parts of the United States.

The Biological Survey has specimens of the roof rat from North Carolina, Georgia, Florida, Alabama, Mississippi, Texas, Arizona, and California. In the last-named State it is abundant in the Sacramento Valley. It is known also from Dismal Swamp, Virginia, and from Cuba, the Bermudas, Trinidad, San Domingo, Costa Rica, Nicaragua, Mexico, and Hawaii. Also, it inhabits many parts of South America, where in places it is the dominant species.

The most destructive of the rat family is the brown rat (*M. norvegicus*). In most parts of the United States it is the common rat about houses and barns in the country and about markets, wharves, and warehouses in cities. It is larger and more robust than either the black or the roof rat, and differs from both in habits. It is more of a burrower, and lives in excavations which it makes under buildings and in loose soil along hedges and river banks. This habit, combined with its greater strength and ferocity has enabled it to supplant the other species in temperate latitudes; but in the warmer parts of America and the Old World it has not been able to drive out the others. The house mouse everywhere holds its own against the brown rat by its ability to escape into retreats too small for the rat to follow.

The brown rat inhabits most of the thickly populated parts of America. North of Panama it occurs generally except in the arid interior, from the Isthmus to the Yukon Valley and southern Greenland. In the Great Basin it is practically unknown, and in New Mexico and Arizona it is confined chiefly to towns along the railroads. The Biological Survey is without records of its presence in Nevada, Utah, Wyoming, Idaho, and the greater part of Montana. The reason for its absence in that region is not understood, but its ability to withstand extreme cold is proved by the fact that it flourished in latitude 78° 37′ north on board Doctor Kane's ship *Advance*, in the Second Grinnell Expedition, during the two winters when that vessel was icebound. It has also adapted itself to the continuous low temperatures of cold-storage warehouses, in which it appears to breed freely.

HISTORY OF THE BROWN RAT.

We know little of the history of this species. Greek and Roman writers make no mention of rats of any kind, but possibly knew the animals and included them in their frequent references to mice. Pallas, in 1778, described the brown rat under the name *Mus decumanus,* and this was generally used until it was found that Erxleben had called it *M. norvegicus* in 1777. Previously, the common name Norway rat had often been used for this species.

The brown rat is generally supposed to be of Asiatic origin. Various modern writers have asserted that it came originally from Persia or India; but W. T. Blanford states that the species is at present unknown in Persia, and that in India the black rat is the generally distributed species, while the brown rat occurs only along the coast and the navigable rivers.[a] This implies that the latter species is a comparatively recent immigrant into India.

As regards the arrival of the brown rat in Europe, two facts are known. The species reached England from some eastern port about 1728 or 1729, and according to Pallas, a little earlier, 1727, crossed the Russian frontier from Asia and soon spread over the greater part of that country.[b] This statement, taken in connection with that of Blanford, makes it highly probable that before this migration the Asiatic home of the species was north, rather than south, of the high mountains of northern India. This view, which has been adopted by several naturalists, is further strengthened by the fact that the animal flourishes better in temperate than in tropical climates.

---

[a] Fauna of British India, Mammals, p. 409, 1891.
[b] Zoographica Rosso-Asiatica, vol. 1. p. 165, 1831.

Possibly earlier and unrecorded westward migrations of the brown rat took place. A few years ago Professor Waile, the archeologist, while making excavations at Cherchell on the coast of Algeria, dug up the skull of a rat, which he stated was contemporary with the Roman occupation of the country under the Cæsars. The skull had but one molar, much worn, but the cranial bones were intact, and French zoologists pronounced the remains as undoubtedly those of the "surmulot," or brown rat.[a] This shows that we have little more than conjectures for the early history of this species.

The brown rat is said to have first appeared in Paris in 1750. It was brought to the United States, probably from England, about the beginning of the Revolution, 1775. According to Audubon, it was unknown on the Pacific coast of the United States in 1851; but Dr. J. S. Newberry thought it must have arrived at San Diego, Monterey, and San Francisco at a much earlier date.[b] Doctor Cooper recorded its arrival at Fort Steilacoom, Washington, as occurring about 1855.

GENERAL DESCRIPTION.

The brown rat differs considerably from the black rat and the roof rat. It is larger, has a shorter head, a more obtuse muzzle, smaller ears, and a relatively shorter and stouter tail. The general color is grayish-brown above and whitish below. The over hairs of the upper parts have black tips. The tail is usually shorter than the head and body combined. The average measurements of adult specimens of the brown rat in the Biological Survey collections are as follows: Total length, 415 millimeters (16.3 inches); tail, 192 millimeters (7.1 inches); hind foot, 43 millimeters (1.7 inches). This species sometimes attains a total length of 19 to 20 inches, and has been known to weigh 24 to 28 ounces and even more. The average weight of an adult brown rat is considerably less than a pound.

The black rat is less robust than the brown rat. It has a longer head, a sharper muzzle, and larger and broader ears (fig. 3). The tail is longer than the head and body combined. The fur is of a sooty, or plumbeous black, color, paler on the underparts. It is much softer and denser than that of the brown rat, and the mixture of very dark and lighter over hairs gives it a peculiar shining appearance. The average measurements of 20 apparently adult specimens in the collection of the Biological Survey are as follows: Total length, 379 millimeters (14.9 inches); tail, 207.4 millimeters (8.1 inches); hind foot, 35.8 millimeters (1.4 inches).

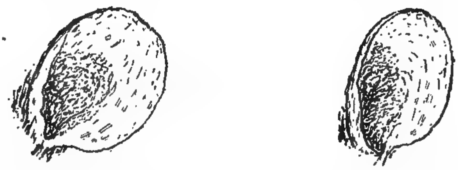
---

[a] Comptes Rendus des Séances de L'Académie des Sciences, Paris, vol. 116, p. 1031, 1893.

[b] Pac. R. R. Reports, Vol. 6, Zoological Report, pt. 2, p. 60, 1857.

The roof rat in general resembles the black rat, except as to color and texture of fur. Above it does not greatly differ in color from the brown rat, but its underparts are usually more yellowish. The fur is commonly shorter and harsher in texture than that of the black rat, but this difference might not always be apparent in specimens of the two forms from the same latitude. The average measurements of 50 adult specimens of the roof rat in the collections of the Biological Survey are as follows: Total length, 393.3 millimeters (15.5 inches); tail, 212.8 millimeters (8.4 inches); hind foot, 36.2 millimeters (1.4 inches).

Both albinism and melanism are frequent among rats, and pied forms also are common. It has been claimed that all the white rats (albinos) of the bird stores are *Mus rattus*, but albinism is by no means confined to this species. Doctor Hatai found that all the colonies of white rats maintained at the neurological laboratories of



a b

FIG. 3A, FIG. 3B.—Ears of brown rat and black rat, showing relative size.

Chicago University and the Wistar Institute of Anatomy, Philadelphia, were of the *M. norvegicus* species.[a] The same is true of all the albino rats in the collections of the National Museum and the Biological Survey. These collections contain also several spotted rats (gray and white) and sooty-black specimens indistinguishable in color from *M. rattus*, all being undoubtedly of the *M. norvegicus* species.

KEY TO THE SPECIES OF MUS IN AMERICA.

Size small. Total length of adult less than 200 millimeters............. *Mus musculus*

Size large. Total length of adult exceeding 300 millimeters.

Ears moderate, when laid forward barely or not reaching eye; tail shorter than (rarely equal to) the length of head and body, darker above than below; color of body normally gray-brown above, white below; hind foot 38–46 millimeters.. *Mus norvegicus*

Ears larger, when laid forward reaching at least to middle of eye; tail longer than head and body, dusky all around; hind foot 33–37 millimeters.

Color grayish-brown above, white or yellowish white below. *M. rattus alexandrinus*

Color blue-black above, slaty below.............................. *M. rattus*

---

[a] Biological Bulletin, vol. 12, pp. 266–273, March, 1907.

HABITS OF RATS.

BREEDING HABITS.

Both climate and food supply affect the rate of multiplication of most rodents. The rat probably increases more rapidly in a temperate and equable climate than in one of great variability. Extremes of heat and cold retard multiplication, decreasing both the number of litters in a year and the number of young at a time. In northern latitudes, apparently, more or less interruption of breeding occurs in the winter months.

Where the country is well settled the food supply of rats is not likely to be deficient; and when the animals have access to stores of grain, the young mature very quickly and probably reproduce earlier than when grain is absent.

The brown rat is more prolific than either the roof rat or the black rat. The female brown rat has usually 12 mammæ—3 pairs of pectoral and 3 pairs of inguinal—although these numbers are not constant, one or more teats frequently being undeveloped. The black rat and the roof rat have only 10 mammæ—2 pairs of pectoral and 3 pairs of inguinal—with but little tendency to vary. Records of actual observations on the number of young confirm the deductions that might be drawn from the above facts. At Bombay, India, during the recent investigations made by the India Plague Commission, 12,000 rats were trapped and examined. The average number of embryos found in pregnant brown rats was 8.1; the highest number, 14. The average for the black rat was 5.2; the largest number, 9.[a]

In temperate latitudes the average number of young produced by the brown rat is undoubtedly greater. Instances of very large litters observed in England are recorded in The Field (London). In two instances 22 and 23 young, respectively, were found in a single nest, though no evidence is offered that these were the progeny of a single female; but in two other cases 17 and 19 embryos were found in gravid females. A dealer in feedstuffs in Washington, D. C., relates that he found 19 young rats in a single nest in his store. Within the past few months the writer has examined four pregnant brown rats taken in traps. The numbers of embryos they contained were 10, 11, 11, and 13, respectively. While we have not enough data for definite conclusions, we may safely state that the average litter for this latitude is not less than 10.

Frank T. Buckland, in Curiosities of Natural History, relates that a white rat which he kept in captivity gave birth to 11 young when only eight weeks old. As gestation in rats occupies three weeks, this animal must have bred when only five weeks old.

---

[a] Etiology and Epidemiology of Plague, p. 9, Calcutta, 1908.

The number of times rats breed in a year is not definitely known, and probably varies considerably with local conditions. Kolazy makes the almost incredible statement that two female white rats, kept by him in confinement and well fed, within thirteen months gave birth to 26 litters of young, numbering 180 in all. One of them produced young regularly at intervals of 25 days.[a]

The writer recently kept two young female brown rats with a male in a large open cage for several months. One of the females gave birth to young on April 15; the other on April 17. The number in these litters was not observed, as some were devoured soon after birth, and all within three days, presumably by the male rat. On May 23 both females gave birth to young, 24 in number, all in one nest.

The known facts concerning the breeding of the brown rat may be briefly summarized as follows: The animals breed from three to five times a year, each time bringing forth from 6 to 19 young. After a gestation period of twenty-one days, the females give birth to their young in nests built in underground burrows or under floors, stacks, lumber, woodpiles, or other shelter. The young are blind and naked when born, but grow rapidly, and young females are capable of breeding when less than three months old.

Early spring and summer are the periods of greatest reproductive activity among rats. Young, however, are to be found every month of the year.

The above statements apply in the main also to the black and the roof rat, but the number of young in a litter is somewhat smaller. The newly born young of the black rat have not the bright pink color of those of the brown and the roof rat, but are bluish, especially on the upper parts. Black-and-white spotted rats are at first bluish-and-red spotted, the red areas representing the white of the adults.

ABUNDANCE OF RATS.

From the foregoing account of the breeding habits of rats, the great difficulty of ridding cities or large areas of the animals may be readily understood. Ordinarily, they breed more rapidly than they are destroyed. Although few are seen in daytime, at night they fairly swarm along river fronts and wharves, as well as in sewers, stables, warehouses, markets, and other places where food is abundant. Their real numbers may sometimes be discovered when any such harbor is demolished.

An ordinary farm sometimes supports an astounding number of rats. In 1901, an estate of 2,000 acres near Chichester, England, was badly infested with the pests. They were systematically destroyed

[a] Verh. Zool. Bot. Gesel. Wien., pp. 731–734, 1871.

by traps, poisons, and ferrets, under the supervision of the proprietor. In this way 31,981 were killed, while it was estimated that tenants at the thrashing had destroyed fully 5,000 more. Even then the property was by no means free from rats.[a]

During a plague of rats on the island of Jamaica in 1833, the number of rats killed on a single plantation in a year was 38,000. The injury to sugar cane on the island caused by the animals was at that time estimated at half a million dollars a year.[b]

The report of the Indian Famine Commission presented to the English Parliament in 1881 affords one of the best illustrations of the number of rats that may infest a country. An extraordinary number of the animals at that time inhabited the southern Deccan and Mahratta districts of India. The autumn crop of 1878 and the spring crop of 1879 were both below the average, and a large portion of each was destroyed by rats. The resulting scarcity of food led to the payment of rewards for the destruction of the pests, and over 12,000,000 were killed.[c]

MIGRATIONS AND INVASIONS.

Migrations of rats have often been recorded. The brown rat is known in Europe quite generally as the migratory rat. The Germans call it the Wanderratte. Pallas narrates that in the autumn of 1727 this species arrived from the east at Astrakhan, southeastern Russia, in such great numbers and so suddenly that nothing could be done to oppose them. They crossed the Volga in immense troops. The cause of this general migration was attributed to an earthquake; but since similar movements of the same species often occur without earthquakes, it is probable that only the food supply of the animals was involved in the migration which first brought the brown rat to Europe.

A seasonal movement of rats from houses and barns to the open fields takes place in spring when green and succulent plant food is ready for them. The return movement takes place in the autumn. This seasonal migration is noticeable even in large cities.

But more general movements of rats frequently occur. In 1903 a multitude of migrating rats spread over several counties in western Illinois. They were noticed especially in Rock Island and Mercer counties. For several years previous no abnormal numbers of the animals were seen, and their coming was remarkably sudden. An eyewitness to the occurrence informed me that as he was returning to his home one moonlit night he heard a general rustling in a near-by field, and soon a great army of rats crossed the road in front

---

[a] The Field (London), vol. 100, p. 545, 1902.

[b] New England Farmer, vol. 12, p. 315, 1834.

[c] British Medical Journal, Sept. 16, 1905, p. 623.

of him, all moving in one direction. The host stretched away as far as they could be seen in the dim light. These animals invaded the farms and villages of the surrounding country and caused heavy losses during the winter and summer of 1904. A local newspaper stated that between March 20 and April 20, 1904, Mr. F. W. Montgomery, of Preemption, Mercer County, killed 3,435 rats on his farm. He caught most of them in traps.[a]

In 1877 a similar migration of rats into parts of Saline and Lafayette counties, Mo., took place.[b] Also, one came under my own observation in the Kansas River valley in 1904. This valley, for the most part, was flooded by the great freshet of June, 1903, and for about ten days was covered with several feet of water. Probably most of the rats in the valley at the time perished in the flood. Yet in the fall of 1903 much of the district was visited by hordes of rats, which remained during the winter and had so increased by the following spring that serious losses to grain and poultry resulted.

No doubt most of the so-called migrations of rodents, were all the facts known, could be accounted for as instances of abnormal reproduction or of failure of food supply in one place, compelling change of habitat. In England a general movement of rats inland from the coast occurs every October. This is known to be closely connected with the closing of the herring season. During the fishing the rodents swarm to the coast, attracted by the offal left in cleaning the herring; and when this food fails, the animals troop back to the farms and villages.

In South America plagues of rats are often periodical, occurring in Parana, Brazil, at intervals of about thirty years and in Chile at intervals of from fifteen to twenty-five years. It has been discovered that these plagues in the cultivated lands follow the ripening and decay of the dominant species of bamboo in each country. The ripening of the seed furnishes for two or more years a favorite food for rats in the forests, where the animals multiply greatly. When this food fails, they are forced to the cultivated lands for subsistence. In 1878 almost the whole crops of corn, rice, and mandioca in the State of Parana were destroyed by rats, causing a serious famine.[c]

An invasion of rats (*Mus rattus*) in the Bermuda Islands occurred about the year 1615. Within two years they had increased so alarmingly that none of the islands was free from them. The rodents "devoured everything that came in their way—fruits, plants, and even trees"—so that for a year or two the people were nearly destitute of food. A law was passed requiring every man in the

---

[a] Moline (Ill.) Evening Mail, Apr. 25, 1904.

[b] Forest and Stream, vol. 8, p. 380, July 12, 1877.

[c] Nature, vol. 20, p. 65, 1879.

islands to keep 12 traps set. In spite of all efforts the animals continued to increase, until finally they disappeared so suddenly that they must have been victims of a pestilence.[a]

FOOD OF RATS.

Instead of being strictly herbivorous, as might be inferred from their dentition, rats are practically omnivorous.

The bill of fare of the rat includes grains and seeds of every kind, flour, meal, and all food products made from them; fruits and garden vegetables; mushrooms; bark of growing trees; bulbs, roots, stems, leaves, and flowers of herbaceous plants; eggs, chicks, ducklings, squabs, and young rabbits; milk, butter, and cheese; fresh meat and carrion; mice, rats, fish, frogs, mollusks, and crustaceans. This great variety of food explains the ease with which rats maintain themselves in almost any environment.

FEEDING HABITS.

Rats resemble squirrels in the manner of holding food while eating. As soon as they have separated a small portion of food from a larger mass, they sit up, arching the back and holding the morsel in the paws and turning it as a squirrel does. After eating, they brush the mouth and fore parts, including the whiskers (vibrissæ), with the paws until all are clean. Rats drink much water, a habit often taken advantage of in placing traps or poisons for them.

Rats generally feed after sunset, but in places where they are not often disturbed they come out and feed in broad day and even in the sunshine.

The roof rat and the black rat are more expert climbers than the brown rat, which is larger and clumsier. In buildings, the brown rat keeps mainly to the cellar and lower parts, where it commonly lives in burrows. From these retreats it makes nightly excursions to the upper parts of the house in search of food. The roof rat and the black rat live in the walls or in the space between ceilings and roofs. They nest in any of these places.

Rats readily climb trees to obtain fruit. In the Tropics the roof rat and the black rat habitually nest in trees and spend much of their time in these arboreal retreats, while the brown rat makes only occasional excursions into the branches in search of food.

In the open, rats seem to have defective vision by daylight. They move slowly and uncertainly. On the contrary, at the side of a room and in contact with the wall they run with great celerity. This fact suggests that the vibrissæ serve as feelers and that the sense of touch in them is extremely delicate. The animals always prefer narrow spaces as highways—another circumstance which may be made use of in placing traps.

---

[a] Popular Science Monthly, vol. 12, p. 376, January, 1878.

FEROCITY OF RATS.

The ferocity of rats has been grossly exaggerated. The stories of their attacks upon human beings, sleeping infants especially, have but slight foundation. If attacked, nearly all rats defend themselves with the teeth; and no doubt a horde of rats, if hungry, would be formidable. Ordinarily the probability of being bitten by rats is remote, and the bite is not poisonous.

The ferocity of rats is mainly exercised against members of their own order. The brown rat is undoubtedly the most formidable of the genus in America, and possibly in the world; yet when captured it adapts itself readily to confinement, and in a few days will take food and water whenever offered. The enmity of this species toward other rats and mice is well known. It is supposed to have destroyed the black rat over the greater part of Europe and America, although it is possible that disease carried by the brown rat was a factor in the disappearance of the other species. That the black and the roof rat in tropical countries have not been displaced by the brown rat is probably owing largely to their more arboreal habits. It is not uncommon in the Far East to find two species of rats living side by side in the same locality. An example is *M. imperator* and *M. rex* living on one of the Solomon Islands. The first is a burrowing species; the other arboreal. In 1877 two native species of rats, *M. macleari* and *M. nativitatis*, were found living together in amity on Christmas Island, in the Indian Ocean.[a] About ten years ago the brown rat was accidentally introduced, and it is now thought that both the native species are extinct.

When pressed by hunger rats become cannibals and destroy their weaker fellows. However, when ordinary food is abundant, cannibalism among rats is rare.

---

[a] Proc. Zool. Soc. 1888, pp. 517, 534.

PLAGUE INFECTION IN RATS.

By George W. McCoy,
Passed Assistant Surgeon United States Public Health and Marine-Hospital Service.

The rat is a known or a suspected factor in the transmission of several diseases, yet at present, and perhaps for many years to come, the most immediate and pressing question that concerns us is its relation to the origin and spread of plague among human beings. For this reason a discussion of the reaction of these animals to natural and to artificial infection with *B. pestis* becomes of prime importance.

Not only are rats believed to be more or less directly responsible for cases of human plague in a community, but in addition, they are believed to be the most frequent medium through which plague is carried from one locality to another, for these animals are good travelers, can live on a very meager ration, and can do without water for a long time if food is available. We have found that on a diet of dry grain alone a rat may live for over a month.

In this connection it may not be amiss to call attention to the importance of the rat as an agent in conveying plague infection to other rodents and especially to ground squirrels. There is every reason for believing that the infection among the squirrels in California was derived originally from rats. Wherry (16) states that more rats than ground squirrels have been trapped in the squirrel burrows in the vicinity of Berkeley, Cal. This shows how easy it might be for rats to infect squirrels and vice versa.

The clinical manifestations of plague in rats are of little importance. It is generally said that the plague-infected rat staggers about with a drunken gait, loses fear of its natural enemies, and is readily captured. Our experience with artificially infected rats indicates that the animals show no marked manifestations of illness until shortly before death when they become quiet, crouch in the corner of the cage, and try to hide.

It is rather surprising to observe that comparatively few plague rats are found dead. In the San Francisco campaign, while no accurate figures are obtainable, certainly not more than 20 per cent of the infected rodents were found dead, the remainder being trapped. This is probably due to the fact that the disease is one of several days' duration, from two to six most frequently, and during this period there are more chances of catching the sick rodent in a trap than there are of finding the body after death, unless the immediate surroundings are known to harbor infected animals and an especially careful search is made for cadavers in the places, often difficult of access, where rats have their burrows and nests.

As plague is a disease that gives rise to such characteristic gross pathological lesions in man and in laboratory animals, it is but reasonable to expect that equally distinctive lesions would be found in the rat, and this we find to be the case.

Skschivan (1), Kister and Schumacher (2), and other writers have observed and recorded the gross lesions of plague in rats. It remained, however, for the Indian Plague Commission (3), which had the opportunity of examining an enormous number of plague rats in Bombay and elsewhere in India, to crystallize our knowledge of this subject and to point out its field of usefulness.

As to the comparative value of microscopical and macroscopical methods of diagnosis, the Indian Plague Commission (3) states that: "The results of tests carried out for the purpose of comparison make it manifest that the naked eye is markedly superior to the microscopical method as an aid in diagnosis, and as the result of our experience we are prepared to make a diagnosis of plague on the strength of the macroscopical appearances alone, even though the other results of cutaneous inoculation and culture are negative and the animal shows signs of putrefaction."

Our experience with rat plague, though limited, leads us to the same conclusion as that arrived at by the Indian Commission in regard to the value of the gross lesions of plague in making the diagnosis. To one who is acquainted with them, these lesions are as characteristic as those of any infectious disease in man. It is quite true that occasionally atypical cases are encountered where the majority of the gross lesions are wanting, and in such cases it becomes necessary to resort to the inoculation of animals or to cultural investigations in order to make a diagnosis. Such cases are, however, if anything, rarer than are atypical post-mortem findings in pneumonia or in typhoid fever in man.

MODE OF EXAMINATION.

A brief description of the actual manner of examining rats for plague infection will be given here.

The rats are immersed in any convenient solution for the purpose of killing fleas and other ecto-parasites that might be capable of carrying infection from a plague-infected rat.

The following plan of handling rats has been found satisfactory in the federal laboratory at San Francisco. The rats are nailed to a shingle by an attendant. Another attendant reads off the address on the tag attached to the rat, puts a check number on the shingle, and records the address from which the rat was taken and the check number on the card shown on page 48. This card is arranged so as to give the data as to the address from which the rat came, its size, sex, and species. After being checked the rats are dissected and finally, after examination by the medical officer, they are removed from the shingle; any plague-infected rats are burned as soon as the necessary investigation has been made. The dissection is made by reflecting the skin from the whole front of the body and neck so as to expose the cervical, axillary, and inguinal regions. The thoracic and abdominal cavities are then opened with scissors.

In the inspection, careful search for buboes must be made in the regions of the various peripheral lymph glands. The abdominal and thoracic organs must be subjected to a careful scrutiny. It is needless to say that this work should be done in a rat-proof, well-lighted building that is provided with water, gas, and sewer connections. The utmost care should be taken to avoid any undue risk of infection. The wearing of rubber gloves is not necessary. Everyone who has to handle infected animals must be sufficiently alive to the danger of infection.

In the extensive work conducted by the Indian Plague Commission (3), attendants were protected with Haffkine's prophylactic. This is undoubtedly a wise precaution and should be taken if possible.

For a worktable on which to dissect the rats we use in San Francisco a table which slopes gently from the sides and ends toward the center, where a drain pipe is attached which leads to a vessel containing a disinfectant. The table is covered with sheet lead.

The layman of average intelligence readily learns to recognize the gross lesions of rat plague and it is wise to train the laboratory attendants to do this. Every rat should, however, be subjected to a careful scrutiny by the physician responsible for the work. The great majority of rats may be put aside after a cursory examination as entirely beyond suspicion of infection. Probably 8 or 10 per cent of them will require a very careful examination for the gross lesions of plague. A card which we have found very useful for keeping records of suspected and infected animals is shown on page 34. Probably all of the species of the genus *Mus* are susceptible to plague infection. I shall, however, confine myself to a consideration of plague in the rats found the world over (*M. norvegicus*, *M. rattus*, *M. alexandrinus*).

In Bombay (18) it has been found that the epizootic among *Mus norvegicus* appears first and is probably responsible for the diffusion of plague among *Mus rattus*. It precedes the infection among *Mus* *rattus* by about ten days, and the opinion is expressed by the Indian Plague Commission that the usual course of the infection is from the *Mus norvegicus* to the *Mus rattus*, and as the latter rodent is a house dweller in India it is the most frequent source of human infection.

In San Francisco the *Mus rattus* population is comparatively small, contributing perhaps 2 per cent of the total rat population of the city; but in the section of the city where the large warehouses are found, especially those where oriental goods are stored, about 15 per cent of the rats taken are *Mus rattus*. So far as concerns plague infection about 5 per cent of the rat cases were in *Mus rattus*. It may be of interest to note that the last infection found among rats in San Francisco was among the *Mus rattus* in a large warehouse near the water front. Two plague-infected rats were found in this building, one October 21, 1908, and the other October 23, 1908. A large number of mummified carcasses, all *Mus rattus*, were found in the building, and it seems not unlikely that a somewhat extensive epizootic had occurred among them. No previous case of rat plague had been found in the city for eighty-five days, though about 25,000 rats had been examined during that period, and none have been found in the six months since, although over 30,000 rats have been examined. Our records show that of 84 infected rats, 79 were *Mus norvegicus*, and the remainder were *Mus rattus*. Some of the latter may have been *Mus alexandrinus*, as the two species (*Mus rattus* and *Mus alexandrinus*) were not clearly differentiated in the earlier examinations.

THE GROSS LESIONS OF NATURAL RAT PLAGUE—ACUTE PLAGUE.

SUBCUTANEOUS INJECTION.

This is the sign which usually first attracts attention. White (4), in discussing plague in rats, states that "the most noticeable postmortem appearance of the plague rat is the engorgement of the subcutaneous blood vessels, together with a diffuse pink color of the subcutaneous muscles, which have a peculiar dry, waxy translucency." It has been our experience frequently to have an attendant who is dissecting rats remark that he had found an infected rat after the first incision was made in reflecting the skin. The injection is dark red, and upon close inspection one sees that the small vessels are uniformly distended with blood. It is usually distributed over the whole surface of the body, but on two occasions we have seen it confined to the side of the body on which the primary bubo was found. A bright pink injection is a rather common finding among rats in San Francisco. It is not likely to be mistaken for the injection of plague infection. Subcutaneous œdema, confined to the vicinity of the bubo, is occasionally encountered.

In our experience in San Francisco an injection identical in appearance with that found in plague infection was found only twice, and in each case there was associated with it a small discharging subcutaneous abscess. There were no other lesions in either case and the pus from these abscesses failed to produce plague in guinea pigs.

In a series of 61 consecutive plague rats in San Fransicso, injection was present fifty-two times, it was confined to the region of the bubo twice, it was unilateral twice, and was general in distribution forty-eight times. It was slight thirteen times, moderate fifteen times, marked sixteen times, intense eight times.

THE BUBO.

This is the most reliable single sign of plague infection, and when present in typical form is enough on which to base a diagnosis which rarely proves erroneous.

The gland involved is usually surrounded by a more marked injection than is present elsewhere, and an infiltration which at times is hemorrhagic. This surrounding hemorrhage which was common in the plague rats described by the Indian Plague Commission was met with very rarely in San Francisco. The gland proper is usually caseous. The contents may be shelled out very readily, though prior to section the gland feels very firm. In the cases seen at the federal laboratory in San Francisco, the contents of the buboes were recorded as being hemorrhagic four times and as caseous twenty-nine times. Pest-like bacilli were noted as present in 18 cases, in 6 of which the "coccoid" form predominated. They were recorded as absent five times.

Indolent enlargement of the lymph glands is very commonly encountered in rats that are not infected with plague. Among old rats probably 15 per cent will show this. Such glands, however, are tough, elastic, and not surrounded by infiltration. They are not likely to be mistaken for the plague buboes. In the leprosy-like disease of rats, the glands may reach an enormous size.

Observers differ as to the location of the primary bubo. Skschivan (1) states definitely the location of five primary buboes in plague rats seen in Odessa in 1901. Two were in the axilla, two in the inguinal region, and one in the neck. Kitasato (5) says: "To judge from the experience of the past it can be suggested that in examining rats particular attention should be paid to their submaxillary and cervical glands and to the spleen. These organs in most cases show the evidence of infection, if there be any." From this it would appear that he regarded the neck glands as the most frequent seat of the bubo. It may be remarked here that his experience was derived from plague rats seen in Asia.

We find a marked difference between the experience in San Francisco and that in Bombay. This is demonstrated in the following

13429—10——3

table, which shows the location in percentage of single buboes in each situation:

	Neck.	Axilla.	Groin.	Pelvis.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*
Indian Plague Commission, Bombay—2,923 rats (3)	75	15	6	4
Wherry, Walker, and Howell, San Francisco (6)—8 rats	12	12	75	....
Federal laboratory, San Francisco—32 rats	....	22	72	6

The American figures are too small to be of much significance, but one is struck with the fact that in Bombay three-fourths of the buboes are in the neck, while in San Francisco three-fourths of all found are in the inguinal region. We have records of only three multiple buboes found in rats in San Francisco, and in no case was either of the buboes in the neck; while in Bombay, to quote from the report (3), "Of the rats with multiple buboes 54.5 per cent had a bubo in the neck." Striking as these figures are, we have collected further evidence that the inguinal region is the commonest location of the bubo in plague rats in this vicinity.

Passed Asst. Surg. J. D. Long, Public Health and Marine-Hospital Service, who has had an extensive experience with rat plague in Oakland, Cal., tells me that the majority of the buboes were found in the groin, very few in the neck. Acting Assistant Surgeon Wherry, Public Health and Marine-Hospital Service, informs me that in a series of plague rats examined after the report made in association with Walker and Howell (6), the cervical bubo was very rarely encountered.

Particular care was taken to look for cervical buboes, as it seemed rather inconsistent to find the other lesions so fully in accord with those found in India, yet to have the location of the bubo to differ so radically. We have not encountered a mesenteric bubo in our work in San Francisco. The Indian Plague Commission found none in over 5,000 naturally infected plague rats. As mesenteric buboes are very commonly encountered in plague infection brought about by feeding, they conclude that the absence of these buboes in naturally infected rats is strong evidence that the infection does not enter by the alimentary canal.

THE GRANULAR LIVER.

Two lesions of the liver are encountered in plague rats. The one most frequently observed is spoken of by the Indian Plague Commission as "fatty" change, though it is explained that this term refers to the naked eye appearance as, microscopically, the lesion is found to be due to a necrosis of the liver tissue. When this change is present the organ is found to be rather yellowish in color and is studded with an enormous number of yellowish white granules which are about the size of a pin head. This lesion, which was very common in the San Francisco cases, is very readily recognized.

The other lesion is a marking of the organ with grayish white spots; "they are typically of the size of a pin's point, and give the surface of the organ a stippled appearance as if dusted over with gray pepper" (3, p. 331). This appearance, which is less frequently encountered than is the preceding one, is more difficult to recognize; indeed the most careful scrutiny is necessary to avoid overlooking it.

Rats that have been fed with certain biological preparations used to destroy rodents (Danysz's virus and similar preparations) often present lesions in the liver resembling those due to plague infection. The granules are, however, larger and more distinct. In these cases the spleen is enlarged and generally granular, but rarely dark and friable as in plague infection.

THE SPLEEN.

The size of the spleen of healthy rats of the same weight varies so greatly that often one can not be sure as to what constitutes an enlargement of this organ.

In plague rats this organ is markedly enlarged, firm, friable, rather dark in color, and occasionally presents small granules under the capsule. As Skschivan (1) pointed out, these granules are not encountered as often as are granules in the liver. At times the organ presents a very distinctly mottled appearance. This latter appearance is much more frequently seen in artificially inoculated rats than in those found infected in nature. We have seen the organ distinctly slate-colored on several occasions.

PLEURAL EFFUSION.

The last sign of rat plague is one of great importance when associated with other suspicious lesions. The effusion is bilateral, and is serous in character, usually clear, though it is occasionally blood-stained. Pleural effusion is rarely found in rats other than those that are plague infected. The following table shows in percentage the frequency of the various macroscopical lesions of acute natural rat plague, as observed in Bombay and in San Francisco:

	Subcutaneous injection.	Bubo.	Granular liver.	Large dark spleen.	Pleural effusion.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Indian Plague Commission, Bombay—4,000 rats	69	85	58	....	72
Wherry, Walker, and Howell, San Francisco—88 rats	59	14	14	68	71
Federal laboratory, San Francisco—62 rats	85	57	87	74	59

It is recognized that the data from the San Francisco records is so much smaller than that from the Indian report that perhaps no just comparison is to be made. However, the figures are quite similar, except for the small percentage of buboes and of liver lesions in the work of Wherry, Walker, and Howell. The work of these observers was done in the early part of the epizootic in San Francisco while the other figures from that city are drawn from records later in the campaign.

No single sign is pathognomonic, though only once have we been deceived by what was regarded as a typical plague bubo. This was in a rat that presented no other suspicious lesions and the inoculation test resulted negatively.

It is a combination of two or more of the signs that is of moment. The subcutaneous injection with a typical liver or these signs associated with a typical spleen afford good grounds for a diagnosis. A rat showing a typical liver associated with a pleural effusion will usually prove to be plague infected, and if a large, dark, firm spleen is also found a diagnosis may be considered as practically established.

As has been pointed out by several writers gross lesions of plague may be distinguished even in rats that are badly decomposed.

CHRONIC PLAGUE.

No case of natural chronic plague has been encountered in San Francisco. Only one case was found among the many hundreds of plague rats examined by the Indian Plague Commission (3, p. 457) in Bombay. However, this commission encountered a considerable number of cases among *Mus rattus* in the Punjab villages of Kasel and Dhand. The lesions were purulent, or caseous foci. They classify these cases as follows: Chronic plague of the visceral type, which is further subdivided into splenic nodules and abscesses, and mesenteric abscesses; chronic plague of the peripheral type in which abscesses are situated in the regions of the peripheral lymph glands.

Plague bacilli were either absent or very scanty upon microscopical examination. They were, however, quite frequently recovered by cultural methods, and in the great majority of the cases the organisms were fully virulent. No evidence was forthcoming to show that this chronic rat plague had anything to do with the recurrence of acute plague among the rats.

We have diligently sought for chronic plague among the rats in San Francisco, but, as we said above, without success, although a considerable number of lesions that correspond perfectly to the description of chronic plague have been submitted to the guinea-pig inoculation test, but invariably with a negative result. An account of the lesions of chronic plague as observed among inoculated rats is given in another part of this paper.

Pound (7) believes that recovery from plague in rats is shown by the presence of pigmented lymphatic glands. Kister and Schumacher (2) mention pigment deposits in the inguinal region, but remarked that they are not characteristic of plague, a view which I believe is correct, as we have frequently seen them in San Francisco among the older rats, in which there was no reason to suspect previous plague infection, and they have been almost uniformly absent in the case of rats that have been experimentally infected with plague but have recovered.

RAT PLAGUE WITHOUT GROSS LESIONS.

Plague infection may be present in a rat without bringing about any recognizable gross lesions. For example: Dunbar and Kister (8) mention a rat, which came from a ship on which plague rats had been found, that had no lesions, and cultures were negative; but a guinea pig cutaneously inoculated died of plague.

Among a considerable number of inoculated rats we have very rarely, perhaps once or twice in a hundred cases, found nothing at the post-mortem examination that would suggest plague infection, yet cultures or inoculation of guinea pigs would demonstrate the presence of *B. pestis.* Such cases are very infrequent, but it should be kept in mind that they do occur. When a large number of rats are to be examined it would be impracticable to inoculate a guinea pig from each rat; and even if one did this the occasionally resistent guinea pig would introduce a larger error than exists by placing dependence upon the gross lesions for a diagnosis.

MICROSCOPICAL EXAMINATION.

The exact weight to be given to the morphology of the organisms found in smears from the organs of a rat suspected of being plague infected is a matter of individual judgment. Smears from a bubo and from the spleen may show no organisms at all, or none even remotely resembling *B. pestis,* and yet by culture and inoculation methods we may be able to demonstrate that the animal is plague infected. Attention has been called to this point by several observers, and every worker in this field has the experience sooner or later.

In other cases the smears will show such numbers of perfectly typical bipolar bacilli and "involution" (coccoid) forms as to leave scarcely any doubt as to the nature of the organism. But even here cases that are not plague are encountered that will deceive even the most experienced. We have been accustomed to put great dependence on the "coccoid" forms of the organism, but late in the San Francisco experience, smears from a splenic nodule that was not regarded as due to plague showed perfectly typical "involution" ("coccoid") forms. Animal inoculations and cultures showed that the tissues contained no plague bacilli.

In addition to these two classes of cases we have a third, where smears show a few typically shaped bacilli, or where a considerable number of typical-looking bacilli are found along with many other bacterial forms. There is no safe rule for reaching a conclusion in these cases, and one must resort to culture or to inoculation methods, or both. In any such case it is always a good plan to let the macroscopical findings have more weight than the microscopical.

The bipolar appearance of *B. pestis* is so largely dependent upon the technique of staining, fixing, length of time the stain is allowed to act, and the length of the washing, that it should never be given great weight. Here, as elsewhere in bacteriology, many errors are to be avoided by not depending too much upon the morphology of the organism under investigation.

BACTERIOLOGICAL DIAGNOSIS OF RAT PLAGUE.

While the gross lesions of rat plague are often sufficiently characteristic to justify a positive diagnosis, and the gross lesions in conjunction with the microscopical examination will in other cases enable us to say definitely that a rat is plague infected, still a certain number of cases occur in which it is necessary to resort to other methods, and there are circumstances, such as the first case in a community, that make a complete bacteriological confirmation of a diagnosis necessary.

This is not the proper place in which to discuss fully the bacteriology of plague. However, a brief outline of what is necessary to establish beyond question the existence of plague infection in an animal will be given.

B. pestis may often be isolated in culture from the tissues (bubo, liver, spleen, or heart's blood) of an infected rat. Unless the tissues are badly contaminated with other organisms, plate or stroke culture will yield a growth of *B. pestis* in pure culture, or isolated pest-like colonies may be transferred to other media.

It is unwise, however, to trust to cultural methods alone. In the majority of doubtful cases it is advisable to inoculate guinea pigs or white rats. The lesions of plague in these animals are quite characteristic, and *B. pestis* may readily be recovered from their tissues if cultures are made at once after death.

A pure culture of the organism under suspicion is obtained from the naturally infected animal or from a laboratory animal inoculated from the one under suspicion. This culture is studied in regard to its morphology; first, on agar, where it grows as a short rod, or often in the shape of a coccus; second, in broth, where it often grows in streptococcus-like chains; third, on agar containing 3 per cent sodium chloride, where most extraordinary alterations in morphology occur, giving large balloon-shaped bodies, objects resembling gigantic cocci and enormous trypanosome-shaped forms, the so-called "involution" forms. These involution forms must not be confused with the so-called "involution" (coccoid) forms of the organism found in smears from animal tissues.

We think it worth while to call special attention to the great diagnostic value of involution forms developed when *Bacillus pestis* is grown on salt agar. No other organism that we have had the opportunity of working with gives forms that are at all likely to be mistaken for those of *Bacillus pestis*, except *B. mallei*, and of course the other points of difference would at once serve to distinguish the latter organism.

B. pestis is Gram negative, though this point is of no great value except to distinguish the "coccoid" forms from pus cocci.

The appearance and character of the culture should be as follows:

Agar.—Smooth, glistening, round whitish colonies which are found to be sticky when touched with an inoculating needle.

Broth.—A scanty surface growth which falls, often in globular masses, when the tube is gently agitated; and a fine flocculent precipitate.

Litmus milk.—Generally rendered slightly acid.

Glucose broth.—Rendered slightly acid. Gas is not formed.

Lactose broth.—Unchanged in reaction. Gas is not formed.

The other cultural reactions are of no material assistance in the identification of the organism. Indeed, in routine work the appearance of the growth on agar and in broth, together with the involution forms on salt agar, are sufficient for identifying the organism.

The plague bacillus is a nonmotile organism, a point worth bearing in mind.

A culture answering the above description when rubbed into the shaven skin of a guinea pig or a white rat should cause the death of either of these animals of plague within ten days, and an organism must be isolated from their tissues after death corresponding to the one inoculated.

If one wishes to be doubly certain, one may inoculate a series of laboratory animals, giving to half of them a sufficient dose of antipest serum. The protected animals should recover, or markedly outlive the controls, which should die in the usual time.

As to the virulence of cultures of the bacillus from cases of rat plague Klein (17) states "that *B. pestis* bred in the rat is of decidedly less virulence than that bred in the human subject; moreover, the former is liable, outside the animal body, to a much greater extent to rapidly lose its virulence." It is evident that in any given epidemic it will be very difficult to say just which strain, rat or human, one is dealing with.

In the case of the strains of *B. pestis* recovered from rats in San Francisco we have seen nothing to justify such an opinion as Klein expresses. The cultures are all highly virulent and retain their virulence under artificial cultivation.

The value of inoculation by the cutaneous method to demonstrate the presence of plague infection in putrefying tissue is well known. We have had one example in which the value of inoculation by this method was proven in the case of a rat that was so badly decomposed as not to admit of any opinion being formed as to whether the animal was infected or not. A rat was brought from a warehouse where a typical plague rat had been taken a few days previously. The specimen was so badly decomposed that the abdominal organs could not be distinguished with any degree of certainty. Smears from tissue that was thought to represent spleen were negative so far as pest-like organisms were concerned. A guinea pig vaccinated from this splenic material died in seven days of typical plague, and a pure culture of *B. pestis* was obtained from its organs.

Kolle and Martini (9) compare the cutaneous method of inoculation to the use of an agar plate in separating plague bacilli from other organisms, and so regularly does *B. pestis* penetrate the skin and infect the animal, and so rarely do other organisms do this, that it offers a certain and accurate method of "filtering out" *B. pestis* from any badly decomposed tissue.

The technique of the cutaneous method of inoculation, or "vaccination" as it is sometimes called, is very simple. An area about an inch square is shaven on an animal's belly, taking care to abrade the epithelium slightly. The culture or suspected tissue is rubbed on this shaven area with a platinum loop or a dressing forceps. Guinea pigs when inoculated in this manner generally die before the seventh day; white rats die a day or two earlier.

Kister (10) uses a drop of juice from an organ rich in bacilli for agglutination experiments with antipest serum. This would appear in many cases to be of very material assistance, and the objection that it is difficult to form a uniform emulsion of the bacteria would be avoided. The well-known tendency of *B. pestis* to grow in clumps in culture is the main reason why agglutination reactions have not been more extensively used in plague work.

Skschivan (1) makes use of Pfeiffer's phenomenon in establishing the identity of a given organism as *B. pestis*.

To assist in the early diagnosis of plague, Dunbar and Kister (8) practiced intraperitoneal inoculation of laboratory animals and used a parallel series of immunized animals. As is well known, intraperitoneal inoculation with plague cultures or infected material leads to the early death of the inoculated animal, and it is evident that the survival of the immunized animal would afford considerable evidence that the material used for inoculation contains *B. pestis*.

PEST-LIKE BACTERIA FOUND IN RATS.

The somewhat general impression that there are a considerable number of organisms that are readily mistaken for *Bacillus pestis* is not justified, provided one gives attention to cultural and inoculation investigations. It is quite true that there are a considerable number of organisms which in smears from tissues are scarcely to be distinguished *morphologically* from *B. pestis*. The similarity, however, usually ends there. A few resemble plague somewhat closely in cultural reactions, and especially *B. pseudotuberculosis rodentium* (Pfeiffer) should be mentioned here; but these differ in pathogenicity. For example, the above-named organism is not pathogenic for rats.

Neumans (11) reviews the subject of pest-like organisms pathogenic for rats, and describes an organism belonging to this group which he isolated from the body of a rat. His work clearly shows that none of the organisms that have been described should cause any serious difficulty in the hands of a careful investigator.

Kister and Schmidt (12) describe an organism closely resembling *B. pestis* in many respects, and with which guinea pigs could be successfully infected by the cutaneous method. This organism, which was also pathogenic for rats and mice, belongs to the hemorrhagic septicæmic group. It differed from *B. pestis* in that it gave no involution forms when grown upon salt agar and was much more rapidly fatal to laboratory animals.

Augeszky (13) observed an epidemic among gray rats in his laboratory which was due to a pest-like organism belonging to the Friedlander group. The animals died after a couple of days of illness. At the post-mortem examination the spleen was found large, soft, and congested. There was a hyperæmia of the intestines, lungs, and liver. In the spleen were found many, and in the heart's blood few, capsulated bacilli, some of which resembled *B. pestis*. The cultural reactions were in nowise similar to those of *B. pestis*. He found that inoculation of rats with a pure culture of this organism sometimes killed in as short a time as twenty-four hours, sometimes as late as two or three weeks, and in some cases the lesions were not very unlike those sometimes produced by *B. pestis*. However, this organism by its different cultural reactions, and the fact that the capsule is usually easily demonstrated, would probably never be a source of any confusion.

ARTIFICIAL INFECTION OF RATS WITH PLAGUE.

For laboratory purposes in general it is customary to use tame white rats, and in plague work they are especially satisfactory, as they are easily handled, rarely harbor fleas, are very susceptible to the infection, and finally and most important, they frequently die a day or two earlier than guinea pigs. At times it may be necessary to use wild rats on account of a failure in the supply of white rats, or for the sake of economy. This may be done very satisfactorily, if one bears in mind the fact that a considerable number of wild rats are more or less immune to plague infection, especially when the infectious material is introduced by Kölle's (cutaneous) method. Therefore, it is always advisable to use three or four wild rats where one white rat would be sufficient. They should be kept in a container of such design that there is no possibility of their escaping. The inoculation is best conducted with the animal under the influence of ether.

MODES OF INFECTION.

Rats may be infected experimentally by the ingestion of contaminated material, and by the application of virulent plague bacilli to a mucous or a cutaneous surface, or by subcutaneous injection of the organism.

Practically we may confine our study to inoculation by the cutaneous method, and to subcutaneous inoculation, when the material is injected in the ordinary manner. A useful modification of the latter method is to make a small pocket under the skin of the abdomen and thrust the suspected material into this pocket. This avoids the necessity of making an emulsion of infectious matter, such as the organs of an animal. The time that elapses between the inoculation of a rat with virulent culture of plague bacilli and its death varies somewhat with the size of the dose and with the mode of inoculation. The following table, compiled from work in San Francisco, shows the day of death of a few white rats and a considerable number of wild rats using the strain of *B. pestis* that was found in the recent epidemic here. Some were inoculated by the cutaneous and some by the subcutaneous method:

Day of death.	White rats.	Wild rats.
Second	....	3
Third	5	27
Fourth	7	41
Fifth	1	30
Sixth	1	9
Seventh	....	8
Total	14	118

The wild rats were all *Mus norvegicus.*

The *lesions* found, when an artificially inoculated rat is examined after death, are in a general way similar to those found in naturally infected rats with certain differences to be mentioned later.

In order to obtain accurate figures as to the frequency of the various lesions in inoculated rats, I have compiled the data from the records of the federal laboratory in San Francisco of a considerable number of wild rats that have been inoculated in the course of various investigations and have died of acute plague. The rats were practically all of the species *Mus norvegicus*.

Artificially inoculated (subcutaneously) plague rats.

	Local reaction.	Subcutaneous injection.	Bubo.	Granular liver.	Enlarged dark spleen.	Pleural effusion.
Present	36	48	19	47	56	18
Very extensive	1	a 2				8
Slight	2	6				8
Total present	39	56	19	47	56	34
Absent	10	4	39	15	3	21
Not recorded	13	2	4		3	7
Total	62	62	62	62	62	62

a Intense.

All of the lesions aside from the local reaction were present and well marked in six cases.

Artificially inoculated (cutaneously) plague rats.

	Local reaction.	Subcutaneous injection.	Bubo.	Granular liver.	Enlarged dark spleen.	Pleural effusion.
Present	16	34	42	58	58	22
Very extensive	1	a 15				6
Slight	6	13				
Total present	23	62	42	58	58	28
Absent	37	6	26	11	8	37
Not recorded	9	1	1		3	4
Total	69	69	69	69	69	69

a Intense.

All of the lesions aside from the local reaction were present and well marked in five cases.

LOCAL REACTION.

The most striking difference between natural and artificial plague in rats is the presence of a reaction at the site of inoculation in the majority of cases where the organism is introduced subcutaneously, and in about a third of the cases where the infectious material is rubbed on the shaven skin (cutaneous inoculation). The local reaction may exist only as a yellowish-brown crust, overlying a granulating surface, and associated with a trifling thickening of the skin and subcutaneous tissue. It may appear as one or more firm papules 3 or 4 millimeters in diameter. The most frequent appearance is a brawny œdematous and blood-stained reaction which extends over an area perhaps an inch in diameter; at times purulent change may be well advanced. Very rarely one finds so extensive an œdema as to cause the lesion to somewhat resemble the widespread gelatinous reaction seen so commonly in the guinea pig. On one or two occasions we have seen an extensive slough at the site of inoculation.

BUBO.

It is very exceptional that one finds in cases of induced plague the typical, firm, caseous bubo surrounded by an infiltrated area, as is so commonly seen in natural infection in rats. The glands are sometimes enlarged and injected without other changes. The commonest lesion, however, is a markedly enlarged gland which upon close inspection is seen to have a number of yellowish points just under the capsule. These points are especially well seen when a section is made through the gland. The gland may be squeezed out of the capsule and it breaks down readily enough when pressure is made upon it; but the uniform necrotic process that one sees so often in natural rat plague is absent.

LIVER.

Granular lesions precisely like those found in natural infections are very common. If the rat has died on the sixth day or later, the ordinary lesions are apt to be replaced by necrotic foci that may be as much as 2 millimeters in diameter.

SPLEEN.

This organ is found mottled more frequently than in natural plague infection, and large granules are much more common.

The subcutaneous injection is rarely so well marked as it is in natural infections.

Pleural effusion of the same nature as that found in natural plague is common. Hemorrhagic foci are not rare in the lungs, and occasionally the organs are partly consolidated.

CHRONIC PLAGUE DUE TO ARTIFICIAL INOCULATION.

Occasionally a rat that has been inoculated but has survived a week or longer, will show, when killed, only an abcess at the site of the injection. Stained smear preparations may show a large variety of bacterial forms. We have not been able to demonstrate the presence of *B. pestis* in these lesions, yet there is no doubt but that the lesion is the result of the inoculation.

A lesion more frequently found is a caseous or a purulent lymphatic gland. If the inoculated rat has been killed about ten days after the inoculation, in some cases one or more of the peripheral lymph glands will be found to be surrounded by an infiltration, and the gland itself will be purulent or less frequently caseous. Such lesions are occasionally met with in rats in which there is no suspicion of plague infection; but they are seen so frequently among rats that have survived artificial inoculation with *B. pestis*, there is no doubt but that in these cases they are the result of the inoculation. In several such cases pest-like organisms have been demonstrated in smears, and acute plague has been produced in guinea pigs by inoculation with the pus found in these lesions. Not infrequently in these cases the spleen will be found enlarged and looking very much like the organ in acute plague, but cultures from this organ in such cases have in my experience remained sterile.

In other cases the only lesions will be found in the spleen. The organ is enlarged and contains a number of caseous nodules. These nodules vary in number from four or five to thirty or forty and in size from the head of a pin to a lesion 0.3 centimeter in diameter. In a number of such cases the nature of the lesion has been demonstrated by animal inoculation. For example, in a series of experiments carried out to determine the susceptibility of San Francisco rats to plague infection a large *Mus rattus* died on the eleventh day after inoculation. The post-mortem examination showed nothing except an enlarged spleen which contained about a dozen caseous nodules, the largest of which was not over 2 millimeters in diameter. The nodules were very firm and the capsule smooth, so that they were held with difficulty with dressing forceps. Cultures from the liver and the spleen remained sterile, but a piece of the spleen was placed beneath the skin of a guinea pig. This animal died of acute plague, and a pure culture of *B. pestis* was isolated from its liver. In some of these cases the liver will show large, distinct, whitish caseous foci. In another case a small *Mus norvegicus* was killed on the twelfth day after a cutaneous inoculation from an artificially infected squirrel. No lesion was found except in the spleen which was not materially enlarged, but which presented two small whitish caseous granules on the surface, neither being over 1 millimeter in diameter. A piece of the spleen containing one of these granules was put under the skin of the belly of a guinea pig. The guinea pig died on the fourth day with the usual lesions of acute plague. Occasionally in these cases of chronic plague punctate hemorrhages or even areas of consolidation are found in the lungs.

THE HISTOLOGY OF RAT PLAGUE.

The most recent and satisfactory work on this subject is that of Ledingham (14), who has studied the lesions of both natural and induced plague in rats. The following is a very brief abstract of his work. The reader is referred to the original for a full study of the subject.

NATURAL RAT PLAGUE.

Two groups of cases are distinguished, first, those in which a large number of *B. pestis* are found in the liver and in the spleen. In the spleen this is accompanied by hemorrhages and congestion of the pulp sinuses and in the liver with congestion of the capillaries. These are early cases.

In the second group, or the later cases, there are extensive reaction changes in the tissues. In the spleen this leads at times to distinct abscess formation, but more frequently to a walling off of the foci of necrosis. In the liver more or less focal necrosis is found; sometimes the areas of "necrosis" may be so extensive that little healthy liver tissue remains. Bacilli are usually to be demonstrated in these areas of necrosis. Giant cells of the Langhans type may be found in the neighborhood of these foci.

The granular appearance of the liver is attributed to "hemorrhages and the focal necroses, together with the fatty changes in the liver cells. It must be understood, however, that a peculiar honeycomb-like vacuolar degeneration of the liver cell protoplasm was far more frequent than any actual, coarse, fatty infiltration. The granular appearance of the spleen is due partly to endothelial catarrh and partly to subcapsular changes."

In experimental rat plague Ledingham found the lesions to resemble those of the first group of cases referred to above. There is usually marked bacteraemia; focal necroses of the liver are scanty.

In a chronic case, minute abscesses were found scattered through the spleen. In the center of the abscesses were found clumps of degenerated bacilli. The areas were walled off by epithelioid and spindle cells and numerous giant cells of the tubercular type.

IMMUNITY OF RATS.

Contrary to the general impression the wild rat is not an animal especially susceptible to plague infection. The Indian Plague Commission (19) found that when rats are inoculated by the cutaneous method from the spleen of infected rats 59 per cent are immune to infection. A series of experiments conducted in the federal laboratory in San Francisco showed that when inoculated with highly virulent cultures of *B. pestis* there is an immunity which is, however, more frequent among the large rats. When inoculated cutaneously with tissue containing large numbers of *B. pestis* from plague infected human beings, rats, or squirrels, about 15 per cent of small rats and about 50 per cent of large ones were found to be immune. There is no good reason for believing that this immunity of San Francisco rats was due to a previous attack of the disease. Indeed, it was known beyond a doubt that some of the immune rats had never had an opportunity of becoming infected with plague in nature and thereby establishing an acquired immunity. We may mention here the fact that has been observed by many workers, and which we have amply confirmed, that rats are readily immunized by antiplague serum.

The subject of the transfer of infection directly from rat to rat by cutaneous or subcutaneous inoculation through a series of the animals is one that is evidently intimately associated with the preceding subject, as it is quite evident that an immune rat or several of them might terminate a series without any actual diminution in the virulence of the organism transferred. It is quite plain that the success of such an experiment would depend largely upon the number of rats used in each transfer. The Indian Plague Commission (19) had no difficulty in carrying infection through twenty-six transfers, using from six to fifty rats in each transfer.

Pound (7) in a series of eight experiments, was never able to convey the infection successfully beyond the sixth rat, using but one rat for each transfer. There was no apparent lessening of the virulence of the organism and each series appears to have been terminated abruptly by encountering an immune rat.

Baxter-Tyrie (15) says:

> It is probable that under certain natural circumstances a reduction in the virulence of the organism is effected and a comparative immunity is conferred on the rats. The infection of immigrant rats is, however, severe, and their arrival is heralded by a heavy mortality. In the same manner an infected rat imported into a fresh locality produces a similar result. This attenuation of virulence is responsible for the condition known as chronic rat plague.

Several experiments conducted in San Francisco to determine this point have given results that I regard as showing merely the presence of a considerable percentage of immunity among the rats. It was observed that in each case certain of the rats died of acute plague even in the last transfer. It was very evident that had certain combinations of immune rats been encountered the experiment might have terminated at any point. On the other hand, by being especially fortunate in using nonimmune rats, the experiments might have given a much higher percentage of cases of acute plague. Unfortunately it was necessary to terminate these experiments in each instance before they could be regarded as completed.

The reason for the natural subsidence of plague among rats in any community is a point about which much more evidence must be obtained before we can speak with any degree of certainty. It may be due to the lack of susceptible material, possibly to a loss of virulence of the organism; but it seems more probable that it is due to a change in the number or relations of the ecto-parasites of the rat.

Adequate measures of rat extermination, while they may never bring about the ideal condition of a community that is free from rats, are, as is shown by the recent experience in San Francisco, of the utmost value in shortening the epizootic.

REFERENCES.

(1) Skschivan (Centralblatt für Bacter., etc., 1903, Vol. XXXIII, No. 4, p. 260).
(2) Kister & Schumacher (Zeit. für Hyg. u. inf. Krank., Vol. LI, 1905).
(3) Indian Plague Commission (Journal of Hygiene, 1907, Vol. VII, No. 3).
(4) White (Medical Record, vol. 67, No. 4, Jan. 28, 1905).
(5) Kitasato (Philippine Journal of Science, Vol. I, No. 5, 1906).
(6) Wherry, Walker & Howell (Journal Am. Med. Assn., April 11, 1908, Vol. L, No. 15).
(7) Pound (1907, Report on Plague in Queensland, B. B. Ham, p. 134).
(8) Dunbar & Kister (1904, Centralblatt für Bact., etc., Vol. XXXVI, No. 1, p. 127).
(9) Kolle & Martini (Deut. Med. Woch., Jan. 2, 1902, Vol. XXVIII).
(10) Kister (Centralblatt für Bact., etc., July 24, 1906, Vol. XLI, No. 7).
(11) Neumans (1903, Zeit. f. Hyg. u. inf. Krank., Vol. XLV, No. 3, p. 451).
(12) Kister & Schmidt (1904, Centralblatt für Bact., etc., Vol. XXXVI, No. 3, p. 454).
(13) Aujeszky (1904, Centralblatt für Bact., etc., Vol. XXXVI, No. 5, p. 603).
(14) Ledingham (Journal of Hygiene, 1907, Vol. VII, No. 3).
(15) Baxter-Tyrie (Journ. of Hygiene, Vol. V, 1905, p. 315).
(16) Wherry (The Journal of Infect. Diseases, Dec. 18, 1908, Vol. V, No. 5).
(17) Klein (The Bacteriology and Etiology of Oriental Plague, MacMillan and Co., London, 1906).
(18) Indian Plague Commission (Journal of Hygiene, 1907, Vol. VII, No. 6, p. 761).
(19) Indian Plague Commission (Journal of Hygiene, 1906, Vol. VI, No. 4).

RAT RECORD CARD.

[Legend: O=Ordinary; W=White belly; R=Red; Go.=Gopher rat; S=Small; M=Medium; L=Large; M. R.=Mus rattus; M. N.=Mus norvegicus.]

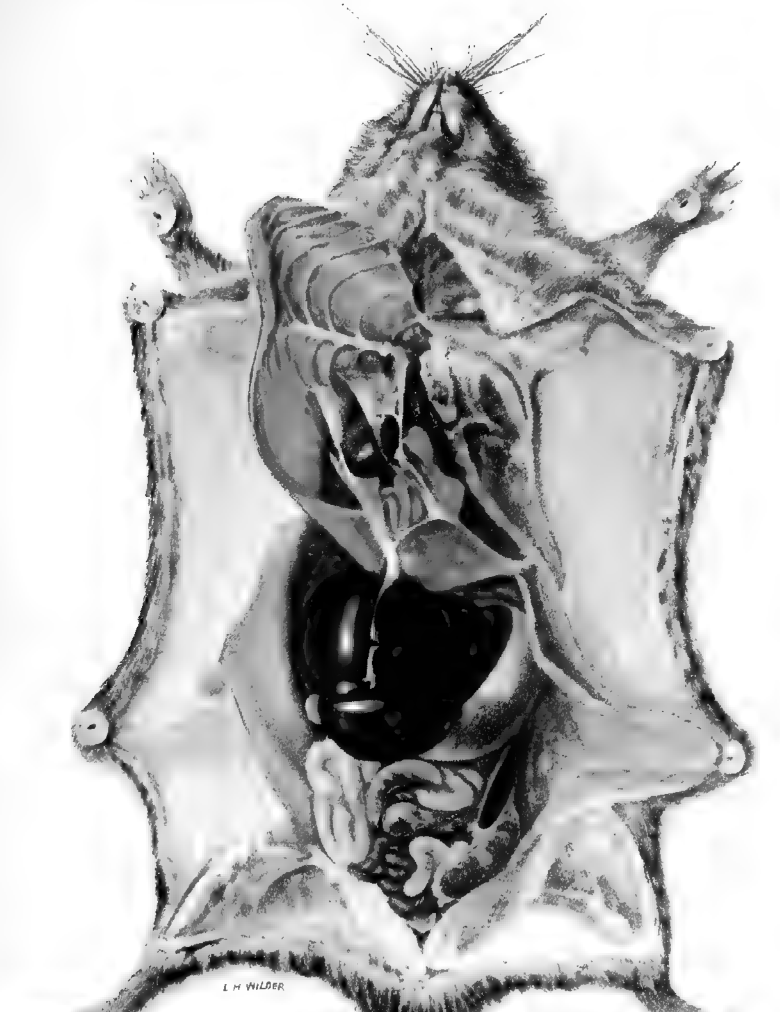
No.	Date.	District No. 6.	Sex.		Size.			M. N.				M. R.		Pregnant.
			M.	F.	S.	M.	L.	O.	W.	R.	Go.	O.	W.	
19	Dec. 10, 1908	401 Fillmore street	1			1				1				
20	do	do		1			1	1						a 7

a Number of fœtuses.

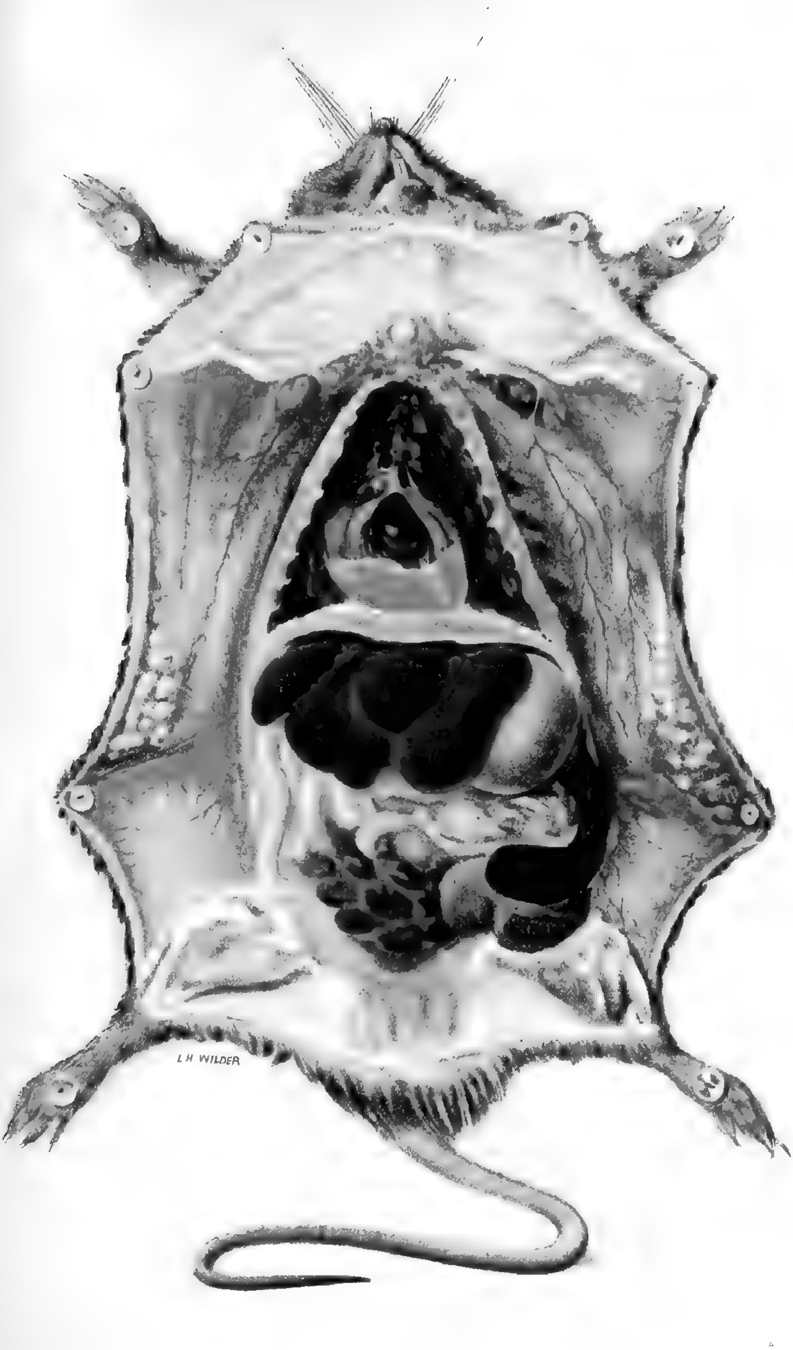
PLAGUE RAT CARD.

PLAGUE RAT NO. 50.

Date: June 20, 1908.
Species: *M. norvegicus*.
From District No. 6, sewer, Haight and Steiner Streets.
Condition: Badly injured by trap; thorax crushed.
Subcutaneous injection: General, marked.
Lymphatic glands, bubo or other lesions: Right inguinal bubo, caseous.
Liver: Typical whitish granules.
Spleen: Large, dark, firm.
Pleural effusion: Unable to say.
Purulent or caseous foci:
Diagnosis from gross lesions: Plague.
Diagnosis from smears: Plague (spleen and bubo).
Cultures: *B. pestis* recovered from liver culture.
Inoculation, guinea pig No. 50 A, +6.25.08.
Vaccination, guinea pig No. 50 B, +6.26.08.
Date suspicious:
Date positive: June 20, 1908.
Date negative:



NECROPSY APPEARANCE OF NORMAL RAT



NECROPSY APPEARANCE OF PLAGUE-INFECTED RAT

RAT LEPROSY.

By Walter R. Brinckerhoff, S. B., M. D.,
Assistant Director Leprosy Investigation Station, United States Public Health and Marine-Hospital Service, Honolulu, Hawaii.

INTRODUCTION.

The leprosy-like disease of the rat is of great interest to leprologists because of its close similarity to the disease leprosy in man. Its practical importance to those engaged in the study of the human disease is increased by the fact that it can be artificially propagated under laboratory conditions from animal to animal and, still more important, can be transferred from the species in which it occurs naturally (*Mus norvegicus*) to a more tractable laboratory animal (*Mus albus*). The brief description of the affection which follows is intended to assist in its recognition and to stimulate the interest of investigators in the disease, which presents problems replete with interest to the study of pathology or bacteriology and of great promise to those engaged in the investigation of human leprosy. It is earnestly hoped that the investigation of this disease will be undertaken in general medical research laboratories, as it is extremely probable that certain of the most difficult problems presented by leprosy in man can be studied in this disease of the rat, and if solved there the information gained can be directly applied to the solution of the analogous problems in the human disease.

REVIEW OF LITERATURE.

The first publication on rat leprosy was made by Stefansky (1903), who observed the disease in Odessa during an antiplague campaign against rats.

Rabinowitch (1903) found the disease among rats in Berlin and confirmed the work of Stefansky.

Dean (1903) discovered the disease independently in London, and in a later publication (1905) reports success in transferring the disease by artificial inoculation.

Tidswell (1906) reports a case of the disease in a rat caught in Sydney, New South Wales, Australia.

The English Plague Commission observed the disease in India in 1907 (Wherry).

Wherry (1908) and McCoy (1908) report upon the finding of the disease in rats caught in San Francisco, Cal.

Mezincescu (1908) has studied the disease and attempted to determine its relationship to known human lepra by complement fixation tests.

DESCRIPTION OF DISEASE.

Geographical occurrence.—It would be premature at present to make didactic statements as to the geographical distribution of the disease, for its discovery has usually depended upon antiplague measures, which are not world-wide in their scope. In spite of this it seems profitable to briefly review the known occurrence of the disease in relation to that of human leprosy. When such a comparison is made we note that the disease is present among the rats of Berlin, a city which is practically free from human lepra. On the other hand in Honolulu, which is an endemic focus of human leprosy, in the examination of 16,000 rats, during an antiplague campaign, no case of rat leprosy was encountered. In addition to the scrutiny of the rats examined for plague in Honolulu, an attempt was made to obtain leper rats by offering a reward for a rat, dead or alive, infected with the disease. This offer was given wide publicity in the Territory, but brought no results.

Occurrence of the disease.—The proportion of rats infected with with the disease in different localities varies greatly, as will be seen in the following table:

TABLE 1.—*Proportion of leper rats to the total rats examined.*

Place.	Observer.	Proportion.
		Per cent.
Odessa	Stefansky (1)	4-5.000
Sydney	Tidswell (5)	.001
San Francisco	Wherry (8)	.210
Do	McCoy (10)	.160
Honolulu	Currie [a]	.000

[a] Personal communication.

Rats in the late stage of the disease are easily recognized by the presence of a patchy alopecia associated with cutaneous and subcutaneous nodules, which may or may not be the site of open ulcers. The diagnosis can be readily confirmed by a microscopic examination of a smear from an ulcer or a nodule, which will show the specific bacillus of the disease in enormous numbers.

Stefansky (1) describes two clinical types of the disease, the one localized particularly in the lymph nodes, the other in the skin and muscles. The glandular type was the more common. Dean (4) thinks that no line of demarcation can be drawn between these clinical types.

Dean (4) and Wherry (7) both mention that attention was attracted to the diseased animals by the fact that they were seen abroad during daylight in an obviously sick condition.

The skin, in a well-developed case of the disease, presents a patchy alopecia coincident with thickening and nodule formation, which is situated in the subcutaneous tissue. The cut surface of the nodules or thickenings is light yellow in color, is clean, dry, and cheese-like. In the region of the nodules the skin is atrophic, and ulcers often form on the prominent parts of the affected area. The subcutaneous fat tissue is diminished in amount. Histologically the process is seen to be practically confined to the subcutaneous tissue and to consist essentially in the presence of cells rich in protoplasm, with vesicular nuclei, whose cell body is more or less completely filled with slender acid-fast bacilli. The subcutaneous fat is replaced by such a tissue. All investigators who have studied the disease agree in emphasizing the similarity of the histology of the lesion to that in leprosy in man.

When the musculature is involved the muscle fibers atrophy and the fibers are infiltrated with the specific bacilli. The affected muscle is friable, and macroscopically grayish-white in color.

The peripheral lymph nodes are commonly involved, though McCoy (10) reports a case in which only the pelvic and mesenteric nodes were diseased, and in the Tidswell case (5) the peripheral nodes were not enlarged. The typically affected nodes are enlarged, sometimes measuring as much as 3 centimeters in the greatest extent, firm, and, on section, opaque pale yellow-white in color. In the experimental disease the writer has frequently found the characteristic bacilli of the disease in peripheral lymph nodes which were very slightly enlarged and presented no macroscopic lesion. Dean (4) has observed invasion of the submaxillary or salivary glands by extension from infected cervical lymph nodes. Wherry (8) notes that in his cases he did not find the submaxillary or cervical glands involved, which fact he contrasts with two early cases in which the skin and adjacent axillary or inguinal nodes were involved.

Microscopically the lymph nodes show large numbers of cells in the sinuses similar to those in the skin lesions. Multinuclear giant cells are frequently observed which may measure as much as 70 to 80 microns (4). The protoplasm of the cells is loaded with the specific bacilli of the disease. The lymph follicles, trabeculæ, and capsule of the glands are also invaded by the bacilli.

The internal organs are relatively slightly affected in the natural disease. Small foci have been found in the liver by Dean (4) and in the liver and spleen by McCoy (10). Wherry (7) reports finding the bacilli in smears from both the liver and spleen. The writer has found microscopic lesions containing the characteristic bacilli in the liver in a case of the experimental disease.

Lesions have been observed in the bone marrow by Dean (4), and the same author states that the nerves are invaded by the bacilli of the disease. McCoy (10) found the bacilli in the urinary bladder in one case.

With a disease showing such a striking similarity to human leprosy, attention has naturally been directed to the bacteriological examination of the nasal mucus. Dean (4) and Wherry (7) have both found the characteristic bacilli in the nasal mucus, while McCoy (10) has failed to do so. The writer's experience has been confined to the experimental disease, and in his animals the nasal examinations have been negative.

ETIOLOGY.

The accepted etiological factor in the disease is an acid-fast bacillus 3 to 5 microns in length and 0.5 micron wide. The bacilli resemble very closely the lepra bacillus of man, but seem to have somewhat greater power to hold carbol-fuchsin stain against mineral acids. The bacilli often have rounded ends and may be curved. The beaded appearance so often seen in lepra bacilli is common. The bacilli show the same tendency to form bundles that is such a marked characteristic of *Bacillus lepræ.* To one familiar with the microscopic appearance of smears from the discharges and lesions of human leprosy the picture presented by similar preparations from the disease of the rat is most striking.

The organism does not grow on the usual culture media—Stefansky (1), Rabinowitch (2), Dean (4), Tidswell (5)—or on certain special media—Dean (4).

The organism is not pathogenic for the guinea pigs—Dean (4), Tidswell (5)—rabbit, mouse, monkey—Dean (4). The disease can be transmitted to black and white rats—Dean (4), Wherry.

SUMMARY.

In the leprosy-like disease of rats we have an affection which closely resembles, both in its etiological factor and in its pathology, the disease leprosy in man. The fact that the disease is readily propagated in a laboratory animal permits of its investigation in any laboratory. It is earnestly hoped that the study of this disease will be taken up by bacteriologists and pathologists, as in this way valuable information may be gained which will be applicable to the problems presented by leprosy in man

BIBLIOGRAPHY.

1. Stefansky, W. K., '03. Eine lepraähnliche Erkrankung bei Wanderratten. Cent. f. Bact., Bd. 33, Orig. S. 481. Baum. Jahres., Bd. 19, S. 496.
2. Rabinowitch, L., '03. Ueber ein Hauterkrankung der Ratten. Cent. f. Bact., Bd. 33, Orig. S. 577. Baum. Jahres., Bd. 19, S. 496.
3. Dean, G., '03. A Disease of Rats caused by an acid-fast Bacillus. Cent. f. Bact., Orig. Bd. 34, S. 222. Baum. Jahres., Bd. 19, S. 494.
4. ———, '05. Further Observations on a Leprosy-like Disease of the Rat. Jour. Hyg., vol. 5, p. 99.
5. Tidswell, F., '06. Note of Leprosy-like Disease of Rats. Lepra, vol. 6, p. 197.
6. English Plague Commission. Jour. Hyg., vol. 7, p. 337. Cited by Wherry.
7. Wherry, W. B., '08. The Leprosy-like Disease among Rats on the Pacific Coast. Jour. Am. Med. Asso., vol. 50, No. 23. Cent. f. Bact., Ref. Bd. 42, S. 664.
8. ———, '08. Notes on Rat Leprosy and on the Fate of Human and Rat Lepra Bacilli in Flies. Public Health Reports, U. S. P. H. and M. H. S., vol. 23, p. 1841. Jour. Infec. Dis., vol. 5, p. 507.
9. Mezincescu, D., '08. Maladie Lépreuse des Rats et ses Relations avec la Lèpre Humaine. Compt. Rend. Soc. Biol., T. 64, p. 514. Cent. f. Bact., Ref. Bd. 42, p. 664.
10. McCoy, G. W., '08. Rat Leprosy. Public Health Reports, U. S. P. H. and M. H. S., vol. 23, p. 981. Jour. Am. Med. Asso., vol. 51, p. 690.

The writer wishes to express his gratitude to Dr. George Dean for histological material from the natural and experimental disease, and to Doctors Wherry and McCoy for rats inoculated with the disease and normal animals for its propagation.

BACTERIAL DISEASES OF THE RAT, OTHER THAN PLAGUE AND RAT LEPROSY.

By Donald H. Currie,
Passed Assistant Surgeon, United States Public Health and Marine-Hospital Service.

So far as is known, the several species of rats that are found about the habitations of man—*Mus norvegicus*, *Mus rattus*, *Mus alexandrinus*, and *Mus musculus*—are naturally subject to but few bacterial diseases as compared to some other animals. Interest in this matter has only recently been aroused, owing to the rôle played by the rat in the spread of bubonic plague. When we consider the immense number of rats that have been examined in connection with antiplague work by trained investigators in recent years, and that to many investigators the thought must have come that the discovery of some rat destroying bacterium would be of the greatest utility, it appears more than probable that few such natural diseases exist.

Plague is the one natural bacterial disease that has demonstrated its power to destroy these rodents in numbers sufficiently large to attract general attention; scientific investigation has only been able to add a few other bacterial diseases, and these are probably for the most part rare ones, causing the death of a very small percentage of the total rat population.

Of the "natural" diseases (i. e., spontaneous, in distinction to diseases that can only be produced artificially, under laboratory conditions) the following are the more important ones:

Rat plague and rat leprosy, which are made the subject of special chapters in this publication, must be mentioned as the most important diseases observed among rat populations.

DANYSZ'S BACILLUS OR BACILLUS TYPHI MURIUM OF LOEFFLER.

These are probably identical organisms, differing only in their degree of virulence, at least their pathogenicity alone distinguishes them in the laboratory. They are both members of the paracolon group. They produce a diffuse cloudiness in broth, ferment glucose but not lactose or saccharose, do not liquefy gelatin nor coagulate milk.

B. typhi murium (Loeffler) is fatal to mice (*Mus musculus*), but not to rats. M. Danysz isolated a bacillus during an epidemic of field mice which was indistinguishable from the above, except that its virulence was capable of being raised to a point where it would destroy a relatively large percentage of rats inoculated with it by feeding. We see from this that, strictly speaking, it is not a natural disease among rats, still there are cases where its virulence has for a time remained high enough to infect a considerable per cent of rats exposed to those that have sickened of it. Not only is this true in cage experiments, but probably it sometimes occurs in nature after the virus is once thoroughly introduced (an article by M. Danysz; also experience of this service in plague in San Francisco, 1903 to 1905), and may therefore be grouped under the list of "natural" infections. This bacillus is unfortunately of a very unstable nature, in so far as its virulence is concerned; some cultures appearing to be avirulent, while others cause an all but absolute mortality among the rodents eating it.

The duration of the disease is variable and appears to depend somewhat on the size of the dose received, as well as virulence of the culture. We have seen death in thirty-six hours or less following ingestion. On the other hand, it may occur in two weeks. Usually it occurs in from six to twelve days. In a typical case when the animal has lived ten or twelve days it is much emaciated, its tissues are dry, and intestinal hemorrhages are sometimes met with. When the disease is much prolonged a pustular eruption may be present over the skin. The organism can often be isolated from the heart blood by plating, such isolation alone affording means of diagnosis. The only present interest this organism has is as a means of destroying the rat. It was believed to be harmless to man, but more recently cases of human illness have been reported that were believed to have been caused by infection with this bacillus.

PNEUMONIA.

We have recently seen a case of lobar pneumonia in a rat in which a diplococcus was present in pure culture. Possibly connected with this is a condition of abscess of lung, which is not very uncommon. The cavity is filled with a creamy or cheesy matter composed of broken-down cells. Often these cavities break into the pleura. Several morphological types of organisms are found, but from their variation this laboratory has regarded them as secondary or accidental, especially as we have failed to demonstrate that this material was infectious.

STAPHLOCOCCUS ABSCESSES.

These are rather common and may occur subcutaneously or in the superficial muscles of any part of the body.

BACILLUS PSEUDO-TUBERCULOSIS RODENTIUM (PFEIFFER).

This organism that infects rats is of interest from its close resemblance to the plague bacillus. It is difficult to distinguish the two organisms by ordinary cultural or animal tests. The earlier writers claimed that *B. pseudo-tuberculosis rodentium* could be differentiated by its power of coagulating milk, but more recently this difference has been found to be an inconstant one.

TOYAMA'S BACILLUS.

Toyama has described an organism which he states is pathogenic for *Mus rattus*, field and house mice (*Mus musculus*), but not pathogenic for *Mus norvegicus*.

It causes congestion of lungs, enlargement of lymph nodes, especially in the neck, and enlargement of the spleen. It was isolated from a natural epizootic among *Mus rattus*. It is a nonspore-bearing bacillus, without capsule, stains without showing bipolarity, and grows upon ordinary media.

Among other bacteria that have been described as causing diseases in rats may be mentioned:

Von Schilling's bacillus, allied to Danysz's organism.

Bacillus "Eris," a member of the colon group.

Bacillus muris, a member of the *B. diphtheria* group.

Of the bacteria that show virulence for rats under laboratory conditions, but, so far as is known, cause no spontaneous outbreaks, the following are the best-known examples:

Bacillus bovisepticus produces a fatal disease bacillus of swine erysipelas (especially for albino rats), and the bacillus of tetanus.

Of the higher fungi (not strictly bacterial) we have:

Streptothrix maduræ produces local swellings when inoculated artificially.

It has been stated that rats occasionally suffer from a disease similar or identical to the affection in man known as favus (*Achorion Schönleinii*).

INFECTIONS OF MICE (MUS MUSCULUS).

This specie of *Mus* is very susceptible to a large number of bacterial diseases when inoculated under laboratory conditions. The following are some of the best-known examples:

B. murisepticus, *Staphlococcus pyogenes*, *Streptococci*, *Diplococcus pneumoniæ*, *B. pneumoniæ* (Friedlander), Diplococcus of pleuro-pneumonia of horses, *B. Typhi murium*, *B. anthracis*, B. of malignant edema, *B. tetani*, *B. mallei*, *B. diphtheriæ vitulorum*, *B. bovisepticus*, *B. suisepticus*, the bacillus of Mereshkowsky, and many others. The last-named organism has been utilized to a limited extent for the destruction of mice about dwellings.

ORGANIC DISEASES OF THE RAT, INCLUDING TUMORS.

By George W. McCoy,
Passed Assistant Surgeon, United States Public Health and Marine-Hospital Service.

The lesions described here are those that have been found in the routine examination of rats for plague infection in the federal laboratory at San Francisco during the past year, in which time approximately 120,000 rats have been examined.

As the subject had no special bearing upon the plague investigations, but little time was spent in examining and recording the nature of organic lesions that were observed. Notes, however, were made of many of the conditions which were encountered, and these notes have been used as the basis of this paper.

It is well known that various lower animals are subject to some of the so-called organic diseases from which man suffers, and not a little experimental work has been done in endeavoring to establish in animals certain of the lesions commonly found in human pathology.

Usefulness of wild rats for laboratory purposes.

We would call special attention to the fact that wild rats suffer spontaneously from cirrhosis of the liver, fatty degeneration of the liver, nephritis, and calculi of the urinary tract, and would, therefore, probably furnish excellent subjects for the experimental investigation of these diseases.

The objection may be made that the very fact that these animals do suffer from these diseases spontaneously makes them unsuitable for experimental purposes, as one could not be certain that any lesions found were not spontaneously developed rather than that they were due to the conditions imposed in an experiment. In reply to this objection we would say that the most of these organic lesions occur so rarely in rats in nature that one could almost ignore them.

The ease with which wild rats are obtained and the readiness with which they adapt themselves to the conditions of life in captivity are factors which should make them more extensively used for laboratory purposes than is the case at present. We have described (New York Medical Journal, Feb. 6, 1909) the methods that have been found useful in keeping and handling these rodents. Without going into details here we may say that if rats of approximately the same size are kept together in a cage there will be practically no mortality from fighting. Of course, there should be no overcrowding. Rats should be fed meat or cheese and plenty of green food such as carrots or cabbage. In our experience in San Francisco it has been found practicable to keep for a year one series of ten inoculated wild rats without any loss. Judging from my experience I have no hesitancy in saying that the natural mortality in the laboratory is higher among both guinea pigs and white rats than it is among wild rats.

It is almost certain that some of the lesions described below are due to animal parasites, or to bacteria, but no such causative agent has been identified.

CIRCULATORY APPARATUS.

We have seen no lesion of the circulatory system with the exception of a few cases of pericardial effusion. The most extreme example was one in which the pericardial sac was dilated to such an extent that it filled almost the entire cavity of the thorax. The fluid in the sac was blood stained and there were a number of recent adhesions between the visceral and the parietal surfaces of the pericardium.

PULMONARY APPARATUS.

Pleural effusion, as is stated in another place, is an important sign of plague infection. A clear, watery effusion has been found in a few cases in rats that were not plague infected.

One example has come under observation of a large *Mus norvegicus* that had both pleural cavities almost entirely filled with a milky fluid. The lungs were compressed and congested. Microscopical examination for animal parasites and for bacteria was negative.

A condition of consolidation of the lungs which closely resembles the stage of gray hepatization in lobar pneumonia in man is seen occasionally. The area may involve half of a lung. Upon microscopical examination one finds the air spaces and the small bronchi filled with leucocytes. There was no cavity formation in any of the cases that have come under observation.

Two relatively common purulent conditions of the lungs are encountered. In the first of these, large and more or less distinctly loculated sacs are found, which are filled with yellow semifluid caseous matter; in the second, the lesion is of much the same nature, but the material in the sac has the consistency of tough, ropy mucus. Aside from the main focus of this sort, numerous smaller areas of the same nature are seen scattered through the otherwise normal parts of the lungs. The extent of some of these purulent processes is remarkable. We have seen cases in which the chest cavity was almost filled by the lesions described.

DIGESTIVE TRACT.

CIRRHOSIS OF THE LIVER.

It was a matter of surprise to find well-marked cases of hepatic cirrhosis in rats, as this disease in man has been pretty generally regarded as very largely due to intemperance in the use of alcoholic beverages. Such an etiology hardly accounts for the condition in the rat. The lesion is by no means rare; well-marked cases are encountered probably as often as once in a thousand rats. We have never seen it in a young rat, probably because the condition develops slowly and the rat reaches adult life before the process is complete. The organ is usually somewhat yellowish, very firm, often, but not always, somewhat shrunken in size. The surface of the whole organ is covered with small, rounded elevations; a typical "hobnail-liver" in miniature.

Microscopically we find various degrees of increase of connective tissue. In a well-marked case the capsule is much thickened, and heavy bands of connective tissue run through the organ in every direction. This increase of connective tissue is most marked in the vicinity of the portal vein and its companion vessels. The microscope will show that in some fields over half of the structure is made up of fibrous tissue. The liver cells that remain appear to be normal. The presence of animal parasites in the liver is frequently associated with a considerable hypertrophy of the connective tissue of the organ. In a majority of cases of hepatic cirrhosis, however, no parasites are to be found. One case has come under observation in which the surface of the liver was covered with a number of flattened, wart-like elevations. Upon section nothing was to be found to account for this except an enormous overgrowth of connective tissue.

FATTY DEGENERATION OF THE LIVER.

A considerable number of cases of well-marked fatty degeneration of the liver have been seen. At times the fatty change is so extensive that the organ floats when placed in water. Microscopically the liver cells are found to be extensively infiltrated with fat granules.

HERNIÆ.

A few ventral herniæ have been observed. In the majority of the cases the sac contained intestine only and this was easily reduced. On two occasions other viscera have been found in the sac; the spleen on one occasion and in another case along with several loops of intestine which were easily reduced there was found the upper extremity of the right division of the uterus which carried a cyst about 1 centimeter in diameter. The cyst was partly adherent to the sac of the hernia. The other division of the uterus was dilated and full of pus. The hernial sac is rarely situated in the median line. One inguinal hernia has been seen.

GENITO-URINARY TRACT.

NEPHRITIS.

Nephritis is a rather common condition in rats. Among the large (old) ones it will be found probably once in every fifteen or twenty examined. It has been found to be especially frequent in rats that are suffering from the leprosy-like disease, as probably two-thirds of those having that interesting infection will show marked evidence of nephritis. The kidney is usually brownish or grayish, mottled, friable and often shows cysts upon the surface and in the substance of the organ. Some of these cysts may be as large as a pea, or indeed even much larger. The capsule strips very readily.

Microscopically the lesions are found to be due partly to epithelial and partly to interstitial change. There is a marked increase of connective tissue rather irregularly distributed throughout the organ. The epithelial cells show various degrees of degeneration; the nuclei are stained very lightly, or not at all; granular change of the protoplasm is well marked. Some tubules are encountered in which the epithelial cells are entirely wanting.

Cyst formation is a conspicuous feature in many of the cases. These cysts vary considerably in size, are often filled with granular débris, and are more or less completely lined with epithelial cells which are sometimes flattened. At times the epithelial lining is entirely wanting. The glomeruli, on the whole, appear to be better preserved than are the tubules. Occasionally areas are found in which there is a very marked round cell infiltration between the epithelial structure. One of the most marked cases of nephritis we have observed was in a large female *Mus alexandrinus*, in which both kidneys were almost entirely replaced by cystic formation, the largest cyst being perhaps 3 centimeters in diameter by 4 centimeters in length, and full of a clear, watery fluid. So extensive was the cystic formation that only a few remnants of kidney tissue remained. Microscopical examination showed a marked increase in the capsular and interstitial connective tissue, a shrinking of the glomeruli, which were surrounded by well-marked fibrous capsules, and extensive cyst formations. The lining of some of these cysts was made up of epithelial cells. Others were quite bare. This rat had, in addition, a large, rough calculus in the urinary bladder.

ABSCESS OF THE KIDNEY.

A female *Mus norvegicus* had on one side of the neck a large cavity full of caseous matter. In each kidney there were five or six circumscribed collections of pus, the largest of which was about the size of a pea. Microscopical sections through these abscesses showed that they were walled off from the kidney structure proper by beginning connective tissue formation. The abscess cavity was filled with polynuclear leucocytes, some of them very markedly disintegrated. The epithelial structure of the kidney proper showed some parenchymatous degeneration.

ATROPHY OF A KIDNEY.

On one occasion we have seen a kidney represented by a very small flattened mass of tissue, the nature of which was not quite clear until microscopical examination showed a few fairly well-defined glomeruli and a few cell groupings suggestive of tubules. Whether the condition was congenital or acquired is not known. The other kidney appeared to be normal in every respect. There was no evidence of compensatory hypertrophy.

VESICAL CALCULI.

The bladder of rats very frequently contains very irregularly shaped, rough, somewhat branching concretions. These concretions are rather soft and tough and are dirty white in color.

In addition to these concretions we have seen several cases of well-marked vesical calculi. In one case 21 smooth round stones which completely filled the bladder were found. The total weight of the stones was 3.8 grams. In another case 6 calculi were found, the total weight of which was 7.8; the largest one weighing 5 grams. In a third case 8 smooth, round stones weighing 1.7 grams were found, the largest of which weighed 0.6 gram. The last two cases were female rats; the sex of the first was not recorded.

In each of these cases the bladder showed to the naked eye very marked evidence of inflammation. The mucous membrane was reddened, villous, and covered with tenacious mucus. In one case in which microscopical examination was made the mucous membrane was found to be covered with pus cells, the surface layers of which were undergoing degeneration.

Diseases of the genital tract in the human race analogous to those mentioned below are so generally regarded as due for the most part to infections from impure sexual relations that it was a distinct surprise to find such lesions in rodents.

In the male abscesses are occasionally met with in connection with the seminal vesicles. We have seen them varying in size from a pea to a sac whose contents would have measured 3 or 4 cubic centimeters. In the female purulent collections in the horns of the bifid uterus are encountered, but they are rare. We have seen cases that were anatomically exactly like the purulent lesions so commonly found in the fallopian tubes of women. In one case one horn of the uterus was closed at both ends and distended by a thin, watery pus into a large sausage-shaped mass about the size of an index finger. The opposite horn of the uterus contained six fœtuses. A very curious case was one in which four fœtuses, each one a little less than an inch in length, were found lying in the midst of a large, yellowish, putty-like mass that distended one horn of the uterus into a balloon-shaped mass about 3 centimeters in diameter. The fœtuses were partly dried, and had evidently been dead for a long time.

TUMORS.

Tumors among rats and mice are not infrequent when these animals are kept in captivity, and the tumors of mice especially have been made the subject of very extensive experiments for the purpose of determining the mode of transmission, the question of immunity, and other subjects that might throw light upon malignant growths in the human family. White or tame rats have been much less used than mice. However, it is interesting to note that the earliest observations on the successful transplantation of a malignant growth from one animal to another was that of Hanau (1), who reported a carcinoma of the external genitals of a white rat and he succeeded in transplanting this tumor into other white rats.

I shall not make any attempt to review the enormous literature on tumors in tame rats and mice, but shall merely mention some of the more important points that have been learned in an experimental way in regard to this subject. The histological nature of the tumors found in white rats was of particular interest, as we wished to compare them with the tumors that have come under observation among the wild rats in San Francisco.

In addition to Hanau's case of carcinoma cited above the following tumors of white rats are mentioned. Herzog (2) observed a cystic sarcoma of the neck of a white rat. Loeb (3) mentions three tumors of white rats; an adenoma in the mammary gland, an adeno-carcinoma of the pancreas, and a carcinoma of the thyroid. Flexner and Jobling (4) report a mixed cell sarcoma of the seminal vesicles of a white rat. This tumor upon transplantation showed a marked tendency to produce metastases. Gaylord and Clowes (5) report cases of fibrocarcinoma of white rats arising apparently from infected cages, and they present evidence that in certain breeding establishments carcinoma is endemic among the white mice. Spontaneous tumors are much more frequently met with in mice than in rats, and a number of epidemics of malignant growths have been observed among mice in captivity.

Tyzzer (6) found in a mouse a primary adenocarcinoma of the lung and an adenoma of the kidney. Loeb (7) found that upon the transplantation of a pure gland-like tumor (carcinoma) which originated in the submaxillary gland of a Japanese mouse both carcinoma and spindle-cell sarcoma were developed, and this observation, that transplanted tumors may give rise to a different histological growth from that which was transplanted, has been made by others. Tyzzer (8) reports 20 spontaneous tumors in mice. Of these tumors 12 were papillary cyst-adenomas of the lung and were mostly very minute, some of them microscopic; 2 were cyst-adenomas of the kidney; 2 lymphosarcoma, 1 of the groin and 1 of the mediastinum, and 4 were adenocarcinoma. These 20 spontaneous tumors occurred in 16 mice, 4 of them having tumors of 2 different types. Ehrlich and Apolant (9) record the occurrence in a white mouse of a mixed tumor (carcinoma sarcomatodes). Saul (10) mentions spontaneous papillary adenocarcinoma and teleangiectatic carcinoma both in the mammary glands of mice.

Saul showed that by planting the common liver worm of the rat (*Cysticercus fasciolaris*) subcutaneously in a mouse he was able to develop a tumor which partook of the nature of a malignant (carcinomatous) growth. It will be seen by an examination of the data presented below relating to spontaneous tumors in wild rats that a considerable number of them have been associated with the presence of the parasite Saul used in his experiments. He also states (11) that Borrel found worms or their remnants in malignant tumors of mice.

When metastases occur in mouse tumors the most usual seat of the secondary growths is in the lungs, thus Tyzzer (12) observed metastases in 4 cases out of 73 mice inoculated with the Jensen tumor. He demonstrated that the metastases took place by the blood vessels, not by the lymphatic channels, although the tumors were of a carcinomatous nature.

Simon (13), who reviews the subject of mouse tumors with special reference to the subject of immunity, remarks that mouse carcinomata, although found most frequently in old females, when transplanted grows equally well in males, and better in young than in old animals. It has been found by some observers that a rat or a mouse unsuccessfully inoculated with a strain is thereafter immune, to even the most virulent strain.

Haaland (14) and other writers have found a marked variation in the susceptibility of different races of mice to mouse carcinoma.

Ehrlich (15) and his co-workers Apolant and Haaland have recorded many experiments in transplantation of tumors of mice. They have demonstrated that moderate heating of a mouse tumor lengthens the incubation period, diminishes the number of successful transplantations, and brings about certain changes in the histology of the tumors reproduced.

Gay (16) found a difference in the susceptibility of white rats from different sources. In his work with carcinoma in rats he found metastases regularly in the lungs and rarely in the lymph nodes. He was able to raise the virulence of the tumor by transplantation of the lung metastases. This increase of virulence was shown by increase in the rapidity in growth, increase in metastases, and the increase of the epithelial elements over the stroma.

Brooks (17) in considering the subject of tumors in animals concludes that true neoplasms are very rare in wild animals living under natural conditions. It should be stated, however, that Brooks refers especially to higher mammals such as are found in zoological collections.

TUMORS OF WILD RATS.

A new growth is found approximately once in every thousand rats examined in San Francisco. Ninety-two tumors have been examined microscopically. Time has been available for the study of but one or at the most two sections from each tumor and while in some cases the diagnosis was easily made in others there was room for considerable difference of opininon as to the nature of the growth. It is obvious that it is hardly fair to expect to make a final diagnosis in every case from one or two sections taken from one part of the growth, and it is possible that further study will throw more light upon the histological nature of some of them.

Location.—The largest number of the tumors have been found in the subcutaneous tissue of either the thorax or of the abdomen, and as the majority of these have been found in female rats we have assumed that they were probably of mammary origin. The growths were occasionally located directly under the nipple, but in such cases the nipple was not retracted, and it was exceptional to find any ulceration. The tumors were very rarely adherent to the surrounding tissue. After the subcutaneous tissue tumors were found most frequently in the liver. Histologically, the most of these growths were sarcomas and the majority of them had a parasite, the *Cysticercus fasciolaris*, in some part of the tumor. This parasite, as is well known, is the larval stage of a tapeworm found in the cat. These tumors of the liver were frequently associated with an enormous number of secondary growths varying in size from a millet seed to 1 centimeter in diameter scattered through the omentum, mesentery, and other abdominal structures.

Several growths have been found in the kidney, mostly of an epithelial nature, one being a particularly well-marked example of a cystic papilloma. A few have been found in connection with other parts of the genito-urinary tract. A large bloody tumor, which upon microscopical examination was found to be an angiosarcoma, replaced a testicle. A large growth, apparently an endothelioma, was found near the end of one horn of the bicornate uterus.

METASTASES.

Metestases have been found in a number of cases of sarcoma and a smaller number of cases of the epithelial growths. Most frequently the secondary tumors were in the liver, the mesentery or the kidney.

Size.—In proportion to the size of the rat the tumors were quite large, scarcely any under 1 centimeter in diameter having been observed, and they varied from this to a growth several centimeters in diameter.

HISTOLOGICAL STRUCTURE.

The following tumors may be regarded as of the connective tissue type:

LIPOMATA.

One typical lipoma has been found. It was located in the subcutaneous tissue of the thorax and was similar in gross and microscopical appearance to the tumors of the same nature in man.

FIBROMATA.

A considerable number of subcutaneous tumors have been typical hard fibromas, others were fibromas in which there were a few cell nests that led to the suspicion that perhaps a malignant change was taking place in the tumor, or that a malignant growth was being converted into one of a benign nature.

SARCOMATA.

Typical spindle cell sarcomas have been encountered a number of times. A few round cell sarcomas were found in which there were usually a number of giant cells, but hardly enough to justify one in designating the growths as giant cell sarcomas. Several other growths have been seen which gave the impression of being sarcomas but left one in some doubt as to whether the tissue might not be of the nature of a granuloma.

Many tumors of the epithelial type were encountered which may be classed together.

ADENOMATA AND CARCINOMATA.

Several very typical adenomas and cystic adenomas have been found. A few tumors were observed that presented the appearance of carcinomas. A large number of growths were observed that apparently stood between the adenoma and the carcinoma and there was room for legitimate difference of opinion about any one of these, and in fact, different pathologists who have examined sections of these tumors have expressed different opinions as to the nature of the growths.

REFERENCES.

1. Hanau (Fortsch. der Med., vol. 7, 1889, May 1, p. 321).
2. Herzog (Journal Med. Research, 1902, vol. 8, old series, p. 74).
3. Loeb (Journal Med. Research, 1901, vol. 6, p. 28; also vol. 3, p. 44, and vol. 17, p. 299).
4. Flexner and Jobling (Journal Am. Med. Assn., 1907, vol. 48, p. 420).
5. Gaylord and Clowes (Journal Am. Med. Assn., 1907, vol. 48, p. 15).
6. Tyzzer (Journal Am. Med. Assn., 1906, vol. 47, p. 1237).
7. Loeb (Univ. of Pa. Med. Bull., 1907, vol. 19, No. 5).
8. Tyzzer (Journal Med. Research, vol. 17, No. 2, p. 155).
9. Ehrlich and Apolant (Berl. klin. Woch., 1907, vol. 44, pp. 399 and 1401).
10. Saul (Centralblatt für. Bact., etc., Aug. 27, 1907, vol. 47).
11. Saul (Centralblatt für Bact., etc., 1909, vol. 49, p. 4).
12. Tyzzer (Journal Med. Research, vol. 17, No. 2, p. 137).
13. Simon (International Clinic, vol. 2, 18th series).
14. Haaland (Berlin. klin. Woch., 1907, vol. 44, p. 73).
15. Ehrlich, Apolant and Haaland (1906, Berlin. klin. Woch., vol. 43, No. 2).
16. Gay (1909, Journal Med. Research, Vol. XX, No. 2).
17. Brooks (1907, Am. Jour. of Med. Sciences, Vol. CXXXIII).

THE ECTOPARASITES OF THE RAT.

By Nathan Banks,
Assistant Entomologist, Bureau of Entomology.

The ectoparasites of the rat fall naturally into three groups, the fleas, the lice, and the mites. These three groups are widely separated from each other, the mites belonging to the class Arachnida, having four pairs of legs, no segmentation to the body, no antennæ, and no compound eyes. The fleas and lice belong to the class Insecta. The lice are near the order Hemiptera, sucking insects without a complete metamorphosis, while the fleas are related to the Diptera and pass through a complete metamorphosis. All of these three groups, however, agree in one character—they are wingless. The mites and lice have flattened or depressed bodies, while the fleas have compressed bodies. All three groups have many other species which infest various other animals. Few, if any, of these parasites confine themselves to the rat, and all can walk or jump in the adult condition, so that they can easily transfer their attentions from one rat to another or to some other host. The majority of them are known to occur on mice, and several of the fleas and mites will readily attack man.

FLEAS—SIPHONAPTERA.

These wingless, compressed insects are known to all, but few have taken the trouble to look at them with much care. The adult female flea deposits her eggs among the hairs or fur of the host animal, but, unlike the eggs of many parasites, these are not fastened to the hairs and fall freely to the ground. These eggs are oval, whitish, and smooth, and about one-half millimeter long. The larvæ escape from the eggs in two to five days. They are enabled to break the egg-shell by a slender process on the top of the head which disappears after the first molt. This larva is a slender, legless, cylindrical creature, whitish or yellowish in color, with a head and 13 segments. There are a few scattered hairs or bristles on the body and at the tip is a pair of corneous processes. On the upper part of the head is a pair of short, slender appendages, the antennæ or feelers. At the front of the head is a pair of biting jaws or mandibles. These larvæ feed on almost any kind of refuse; some have been reared on the sweepings from rooms. There is always some organic matter in this refuse, and this is doubtless their nourishment. The larvæ in houses usually crawl into cracks or under carpets and feed on the dust that occurs in such places. Those that infest wild animals probably feed on the refuse in the nests or retreats of these animals. They remain in the larval stage from a week to ten days, sometimes two weeks, molting the skin three times in this interval. Then they spin flat, white, silken cocoons, in which they transform to the pupal stage. Sometimes the cocoon is covered with particles of dust. In from five to eight days the adult flea emerges from the cocoon. The period of their transformation is affected by the temperature and moisture. In warm, damp weather a generation may develop in ten days or two weeks, but usually about eighteen days to three weeks elapse from the egg to adult. Although some moisture

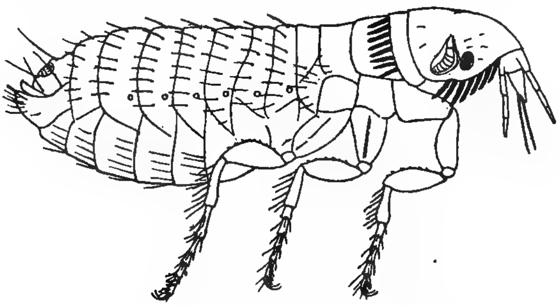


FIG. 6.—Flea, showing the various parts.

seems necessary to their development, an excess is apt to destroy the larvæ.

The leaping ability of adult fleas is familiar to all. No part of the leg is particularly enlarged, so that the jump is made by the entire leg as in the leaf-hopper insects, and not by the hind part of the leg as in grasshoppers and flea-beetles. The size of fleas is not as variable as in many insects. Most are about 2 to 3 millimeters long, while the range is about 1.5 to 6 millimeters. The adult flea has a hard, strongly chitinized body. The head is small, and on each side bears a short jointed antenna, which may repose in a groove or depression. Most species have a small, simple eye, but several forms are normally without eyes. The sides of the head below the antennæ are called the genæ. At the lower front end of the head is the mouth and mouth parts. The latter consist of a pair of triangular maxillæ with jointed maxillary palpi and a beak or proboscis made up of one median and four lateral pieces. The outer pair of lateral pieces is the labrum with the imperfectly jointed labial palpi.

They serve as a sheath for the other organs, which are more slender. The inner pair of pieces are considered to be the mandibles and the median piece a labrum or hypopharynx. Others call this piece the unpaired piercing organ, the lingua, or the syringostome. There are other interpretations of the homologies of the mouth parts, but the above is the most generally adopted one. The labrum and the mandibles are roughened and constitute the piercing organs which the flea inserts into the host to tap a blood vessel. On the lower part of the head there is frequently a series or comb of stout spines. Similar spines sometimes occur on the posterior border of the pronotum. These series of spines are called "ctenidia," and they are of great value in classification. Behind the head are three segments, or zoonites, each bearing a pair of legs. These together form the thorax. The upper surface is called the notum (pronotum, mesonotum, etc.). The sides are the pleura—sometimes "epimera" is used; and the ventral part is the sternum. Each of the thoracic segments has a spiracle, or a breathing pore, on each side. The first segment of the thorax, called the "prothorax," is shorter than the others, and, as above stated, frequently has a row of ctenidia, or spines, on its posterior border. The next segment is the mesothorax, and the third the metathorax. The metathorax usually has some stout bristles in rows on its pleura, which are enlarged and called "epiphyses," formerly called "squama aliforme." The basal one or two segments are sometimes partly covered by the epiphyses or the metathorax. These segments consist of a dorsal plate, or tergite, and a ventral plate, or stermite. Behind the thorax is the abdomen of 9 apparent segments. Seven of these segments have a spiracle or breathing pore on the sides. The last segment, or pygidium, bears the genital organs; in the male certain processes called "claspers" at each side of the genital opening. The anal aperture is at the end of the ninth segment between the dorsal and ventral plates. The claspers have a main curved part, and a slender backward projection called the "manubrium," and at the apex an articulated claw-like process called "the movable finger." At the tip of the abdomen of the female there is a short median piece called the "style." The legs consist of five parts: The coxa, a large basal piece; the trochanter, a minute piece at the end of the coxa; the femur, which is usually slightly swollen in the middle; the tibia, which usually has stout bristles or spines on its posterior side; and the tarsus, which consists of five parts or joints. The basal joint is often the longest, and the comparative lengths of these joints is expressed by a formula, as 60–45–32–18–30. The last, or fifth, joint has been called the "metatarsus," but this name is better applied to the basal joint. At the tip of the last tarsal joint is a pair of stout claws. The coxæ of legs II and III show a longitudinal suture.

Fleas as a rule prefer certain hosts, but are not as particular in this regard as are many parasites. Those species which are best known are found to attack several hosts, including man. This catholicity of taste is what makes them dangerous parasites, the possible transmitters not only of plague, but also of consumption, leprosy, etc. The fleas are treated by various writers under other names, such as *Aphaniptera*, and *Suctoria*. About 300 species are described, and perhaps as many more will be gathered by collectors. Formerly all fleas were kept in the genus *Pulex;* now they are arranged in many genera, and these genera grouped into families. No less than eight such families are recognized by some authorities on this group. The species that occur on rats belong to three families, which may be separated as follows:

1. Thoracic segments much shortened and constricted; labial palpi apparently not jointed; third joint of antennæ without subjoints; no ctenidia; abdomen of female becomes more or less swollen .... *Sarcopsyllidæ*
   Thoracic segments not shortened nor constricted; labial palpi with joints; third joint of antennæ with several more or less distinct subjoints; ctenidia often present; abdomen of female never distinctly swollen 2
2. Posterior tibial spines in pairs.. *Pulicidæ*
   Posterior tibial spines mostly single and more numerous .... *Ctenopsyllidæ*

CTENOPSYLLIDÆ.

To this family belongs the *Ctenopsylla musculi* Dugès.

This was formerly placed in the genus *Typhlopsylla*. The head is rather acute in front and has four ctenidia each side; the eyes are very small; the pronotal comb has 22 spines; each dorsal segment of the body has two rows of hairs; the basal row of smaller hairs. The proportions of joints in the hind tarsus are: 45–25–17–8–14. Length 1.8 to 2.5 millimeters. This species is abundant on rats and mice in Europe and other countries; recently it has been taken in California and Florida on rats and mice.

PULICIDÆ.

This family includes the greater number of fleas. They have been arranged in many genera, six of which have been taken from rats. These are separable as follows:

1. Head without ctenidia; eyes distinct.....................................2
   Head and pronotum with ctenidia; last tarsal joint with four pairs of lateral spines...5
2. Pronotum with ctenidia; female with one antepygidial bristle on each side .... *Hoplopsyllus.*
   Pronotum without ctenidia...3
3. Last tarsal joint with four pairs of lateral spines; female with one antepygidial bristle each side...4
   Last tarsal joint with five pairs of lateral spines; female with two to five antepygidial bristles each side.................................. *Ceratophyllus.*

4. Mesosternite very narrow, without internal rod-like incrassation from the insertion of coxa upward . . . . *Pulex.*
   Mesosternite with a rod-like internal incrassation from the insertion of coxa upward . . . . *Xenopsylla.*
5. Eyes rudimentary; female with two to five antepygidial bristles each side . . . . *Neopsylla.*
   Eyes distinct; female with but one antepygidial bristle each side . . . *Ctenocephalus.*

Hoplopsyllus, one species, described as a *Pulex.*

Hoplopsyllus anomalus Baker.

The mandibles scarcely reach halfway down on the anterior coxæ; upon each are two large spines; the pronotal comb has about nine spines each side; and each abdominal segment has but a single row of bristles. The hind femora have six to eight bristles on the side; the proportions of the joints in the hind tarsus are: 26–16–8–5–13. Color, dark reddish brown. Female, 2.5 millimeters; male, 1.5 millimeters.

Described from a spermophile from Colorado and recorded by Doctor Fox and Professor Doane from *Mus norvegicus* from California.

Pulex.—Of this, the typical genus of the family, but one species has been recorded from rats.

Pulex irritans Linn.

The mandibles reach about halfway down on the anterior coxæ; the head is regularly rounded in front; there are no transverse rows of bristles on the vertex, and but one row of bristles on each abdominal tergite. The proportions of the joints in the hind tarsus are, 50–30–18–12–32. Color, usually yellow brown. Male, 1.6 to 2 millimeters; female, 2 to 3.5 millimeters.

This, the human flea, is quite cosmopolitan, but more abundant in warm countries than elsewhere. It occurs on many domestic animals and has frequently been taken from rats in California and elsewhere; it also occurs on skunks.

Xenopsylla.—This genus includes the following species, formerly placed in the genus *Loemopsylla.*

Xenopsylla cheopis Rothschild.

The mandibles reach nearly to the end of the anterior coxæ; there are no ctenidia on the head or pronotum; the eyes are distinct; each abdominal tergite has but one row of bristles; the hind femur has a row of about eight bristles; the proportions of the joints in the hind tarsus are as follows: 46–30–16–10–20. Color, light brown. Male, 2.5 to 3.5 millimeters; female, 4 to 5.5 millimeters.

This is a true rat flea, but will readily bite man, and is the species chiefly concerned in transmitting the bubonic plague. It is widely distributed, especially in seaport towns.

Ceratophyllus.—Fleas of this genus are abundant on many kinds of small mammals, especially rodents. There are a great many species and some are so closely related that it is not easy to identify them. Of the eight species recorded from rats, four have been taken in this country. It is not practicable to tabulate these eight species, but the four that occur in our country may be arranged as follows:

1. Hind tarsal joint II with an apical spine much longer than joint III..... *acutus.*
   Hind tarsal joint II with spines not longer than joint III....................2
2. Pronotal comb of about 26 spines.. *niger.*
   Pronotal comb of about 18 or 20 spines.............. *fasciatus* and *londinensis.*

Ceratophyllus niger Fox.

This species has the pronotal ctenidia of about 26 spines; there are a few hairs on the inner surface of hind femur; apical spines of second joint of hind tarsus not longer than third joint; three hairs in front of the eye and three in front of these; movable finger of claspers with five slender bristles on the outer edge. Color, very dark brown. Length 3.5 millimeters.

Taken in California from *Mus decumans* and from man.

Ceratophyllus acutus Baker.

This species is readily known by having a spine at tip of the second joint of hind tarsus longer than the third joint and reaching over onto the fourth joint; the abdominal tergites have each two rows of bristles; the male claspers are very large and long, sickle shaped. Color, pale brown. Length, 3 to 3.5 millimeters.

It was described from a spermophile, but Doctor Fox has taken it once from a rat in California.

Ceratophyllus fasciatus Bosc.

There are 18 or 20 spines in the pronotal comb; there are three bristles in front of eye and in female two, and in male four in front of these; there are three or four hairs on the inner surface of the hind femur; the proportions of joints in the hind tarsus are 50–33–20–11–21. The manubrium of the male claspers is very long and slender, and some of the bristles on the movable finger are as long as the joint. Length, male, 1.8 millimeters; female, 2.5 millimeters.

It has been recorded from California on rats, mice, skunks, and man. It is also common in Europe and elsewhere on rats, mice, and other small animals.

Ceratophyllus londinensis Rothschild.

This is allied closely to *C. fasciatus*, and is best separated from that species by the shape and armature of the genital parts; the manubrium is not as long as in that species, and the bristles on the movable finger are shorter; the third joint of the maxillary palpi is proportionally longer than in *C. fasciatus*. There are three bristles in front of the eyes and four or five in front of these; there are a few hairs on the inner surface of the hind femur; the proportions of the joints in the hind tarsus are 46–30–18–11–18.

It has been recorded by Doctor Fox from *Mus rattus* in California, and is known from rats and mice from several parts of Europe; the *C. italicus* Tiraboschi is the same species.

The four other species of this genus found on rats and not yet found in our country are closely related to *C. fasciatus*, and distinguished chiefly by the shape of the male genitalia.

Ceratophyllus mustelæ Wagner.

This species has no series of hairs on the inner surface of the hind femur; there are three bristles in front of the eye and six in front of these; the pronotal comb has 18 or 20 spines; the proportions of the joints in the hind tarsus are 47–37–20–13–20; the movable finger of the male clasper has a long process below not seen in other forms. Occurs (according to Rothschild) on rats in Europe.

Ceratophyllus pencilliger Grube.

This species also has no hairs on the inner surface of the hind femora. The pronotal comb has 18 spines; there are three bristles in front of the eye and four in front of these; the proportions of the joints in the hind tarsus are 52–36–23–14–24; the outer corner of the movable finger of the male clasper has two little rounded processes. It was described from Siberia, but according to Rothschild occurs on rats in Europe.

Ceratophyllus consimilis Wagner.

This species is very close to *C. fasciatus*, and has some fine hairs on the inner surface of the hind femur; there are but two bristles in front of the eye and in front of these a few finer hairs; the proportions of the joints in the hind tarsus are 42–30–20–11–19; pronotal spines 18. Occurs on rats in Russia.

Ceratophyllus lagomys Wagner.

This species also has a few fine hairs on the inner surface of the hind femur; 18 spines in pronotal comb; there are three bristles in front of eye and one in front of these; the proportions of the joints in the hind tarsus are 53–32–20–11–22; the outer corner of the movable finger of the male clasper has two little processes, similar to those on *C. pencilliger*. Occurs on rats in Europe.

Ctenocephalus.—The common fleas on cats and dogs, as well as on man, belong to two species long kept under one name (*C. canis* or *C. serraticeps*), but lately shown by Rothschild to be distinct. Both have a comb of 8 spines on the head and 16 spines in pronotal comb; the proportions of joints in the hind tarsus are 40–24–15–10–24. Both are occasionally taken on rats in this country. They may be separated as follows:

1. In the female the head is fully twice as long as high (seen from side); the first spine of genal comb is two-thirds the length of the second; in male the manubrium of claspers is barely enlarged at tip; and with two rows of hairs on disc of movable finger .... *C. felis* Bouché.

In the female the head is less than twice as long as high (seen from side); the first genal spine in the head comb is only about one-half the length of the second; in the male the manubrium of clasper is very distinctly enlarged at tip; but one row of hairs on the disc of the movable finger.................... *C. canis* Curtis.

Neopsylla.—One species of this genus has been described from the brown rat in Europe.

Neopsylla bidentatiformis Wagner.

The eyes are very small; there are 4 pairs of lateral spines beneath the last joint of the hind tarsus; the comb on head consists of but 2 stout spines, below the middle of the antennæ; the pronotal comb has 18 spines; the proportions of the joints in the hind tarsus are 43–33–21–12–21.

Length: Male, 2 to 2.3 millimeters; female, 2.3 to 2.5 millimeters.

Not yet found in the United States; described from Russia.

SARCOPSYLLIDÆ.

The fleas of this family are commonly called "chigoes," "jiggers," or sand fleas. The head is usually larger proportionally than in the other fleas; there are no ctenidia on head or pronotum; the thoracic segments are extremely short, and in the female the abdomen enlarges with the development of the eggs. They do not hop about as other fleas, but remain on the spot to which they have attached until they die. Frequently the adjacent skin grows over them, forming a swelling of considerable size.

Three species belonging to two genera have been recorded from rats.

1. Angle of head acutely produced; fifth tarsal joint of hind legs without heavy spines; few spines on the legs.. *Sarcopsylla.*
   Angle of head not produced, obtuse; fifth tarsal joint with heavy lateral spines, and other spines on other parts of the legs........................ *Echidnophaga.*

Echidnophaga.—Two species of this genus are known from rats; one, however (*E. gallinacea*), can hardly be called a normal parasite, but rather of accidental occurrence. The genus has also been called *Argiopsylla* and *Xestopsylla.*

1. Bristles at end of second joint of hind tarsus about as long as next three joints; palpi about one-half the length of mandibles.................. *E. rhynchopsylla.*
   Bristles at end of second joint of hind tarsus about as long as next two joints; palpi about two-thirds the length of the mandibles.............. *E. gallinacea.*

Echidnophaga rhynchopsylla Tiraboschi.

The body is about twice as long as broad and shining brown; there is but one hair in front of eye, and four on each metathoracic pleuron; mandibles larger than in *E. gallinacea,* and the spiracles are much higher up on the sides than in that species. Length, 1.4 to 1.8 millimeters.

Taken from *Mus rattus* in Italy.

Echidnophaga gallinacea Westwood.

This species has the body almost as broad as long, and of a red-brown color; 1 bristle in front of eye and 6 on each metathoracic pleuron; each abdominal tergite has on each side near the median line a single hair; the spiracles are situated well down on the sides. Length: Male, 0.8 to 1.2 millimeters; female, 1 to 1.8 millimeters.

This species is a fairly common pest of poultry and dogs in warm countries, and is called the "chicken flea." It has been taken from rats in Italy.

Sarcopsylla.—This genus includes the *S. penetrans*, which attacks the feet of various animals, including man, in the Tropics. This species has not yet been recorded from rats, but an allied species is described from Brazilian rats.

Sarcopsylla cæcata Enderlein.

Color, clear yellowish. Eyes rudimentary; lower anterior corner of coxæ prolonged in a tooth; tarsal joints very short; claws long, but little curved, and almost hair like. The body of a swollen female is about 5 millimeters long.

Taken from *Mus rattus* in Brazil.

LICE—ANOPLURA.

The insects known as Pediculi, or lice, are parasitic during their entire life on various mammals, including man. They are flat, rather elongate, wingless insects, with a small head and stout legs, which end in a strong claw, opposable to a projection at the tip of the penultimate joint. The simple antennæ, three to five jointed, are inserted in a concavity on the side of the head. The mouth parts are of a very peculiar nature, and not yet homologized with the cibaria of other insects. There is a short beak or proboscis in front, with recurved spines or hooks on its dorsal and lateral surfaces. Through this beak extends a slender stylet, that is formed of three parts; a ventral channeled piece, perhaps a labium; a dorsal piece, consisting of two pieces fused together, perhaps the maxillæ; and a median tube, possibly the hypopharynx. The stylet is used to pierce the skin of the host, and the blood is sucked up through it. There are no palpi. On each side of the head there is a small, simple eye. The thorax shows only incompletely the division into the three parts; there is a large spiracle above on each side. The abdomen shows eight segments, six of them have a spiracle, or breathing-pore, on each side, the basal and apical segments being without them. All of the segments bear a few simple hairs or bristles; the longest are on the posterior segments. The legs are stout and prominent; they consist of a broad coxa, a small trochanter, a longer femur, a tibia with an apical process, and a tarsus of one joint and a very large terminal claw. At the apex of the tibia, just within the projection, is a sucking disc. This, the projection, and the claw form the apparatus to hold fast to the hair of the host.

Lice usually walk sideways, but do not travel much, and they keep close to one host. The eggs are slightly elongate and fastened to the hair of the host. They hatch in about ten to fifteen days, the young coming out of the top of the egg. These young do not differ much in structure from the adults, but are paler in color. They molt their skin a few times, probably four, before they reach the mature condition. The males are less numerous than the females, and ordinarily smaller. There are several generations each year, dependent doubtless on the temperature; but the life history is not thoroughly known for any species. After sucking the blood the abdomen of the louse becomes somewhat distended, very noticeably so in some species.

The sucking habits of the lice render them dangerous parasites and capable of transmitting a disease from one host to another. For-

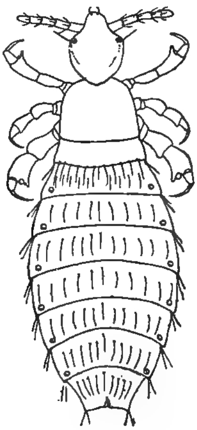


FIG. 7.—Louse (*Polyplax spinulosus*).

tunately they do not readily change hosts so that they can not be considered quite as dangerous as some more active parasites. However, several species have already been shown to carry diseases in laboratory experiments. Therefore it is probable that some of them will be connected with the origin and diffusion of certain diseases of animals.

The Anoplura, or lice, have often been treated in connection with the Mallophaga, or biting lice. This is doubtless because they frequently occur on the same animal, and have a general resemblance to them. However, they have no real affinity to these insects, and the general opinion is that they are more or less related to the Hemiptera. Sometimes they are treated as a group or section of the Hemiptera, but also as a separate order, under various names as Siphunculata, Lipognatha, Pseudorhynchota, and Ellipoptera.

There are about 50 or 60 known species which are arranged in 15 genera and 4 families. Four species belonging to three different genera have been recorded from rats; a number of others are known from mice and other rodents, and some of these will probably yet be taken upon rats.

These four forms are separated, as follows:

1. Eyes large and distinct; beak very short; thorax plainly longer than broad .... *Pediculus capitis.*
   Eyes small, beak longer; thorax about as broad as long 2
2. In male the pleura of abdominal segments 3 to 6 above and below have a prominent tooth-like projection; a tooth on the hind femur of female .... *Hoplopleura acanthopus.*
   In male the pleura of abdominal segments without such projections; no tooth on hind femur of female 3
3. Last joint of antennæ much more slender than those before; an acute tooth at sides of segments 4 to 7; head much narrower in front; antennæ two-thirds as long as head .... *Polyplax miacantha.*
   Last joint of antennæ not much more slender than others; head quite broad in front; antennæ as long as head .... *Polyplax spinulosus.*

Pediculus capitis De Geer.

It is pale grayish in color, with faint dark markings at the sides of the thorax and abdomen; the last segment of the abdomen in female is bilobed. The head is longer than broad and tapers in front. Length, 2 millimeters. This is the head louse of man, and is said to have been taken from rats, and is claimed to be able to transfer plague from rats to man. Its occurrence on rats, however, appears to be very uncommon.

Hopopleura acanthopus Burmeister.

In the male the pleura of the abdominal segments 3 to 6, which reach up on the dorsum and over on the venter, have at their inner ends a prominent projection, toothed in all except the third on dorsum and the sixth on venter, which are spine-like. The head is but little longer than broad, broad in front; and in the female there is a recurved tooth on each hind femur. The last segment of the female abdomen is bilobed behind. Length, 1.3 millimeters. It has been taken from rats in Europe, but is more common on species of *Microtus.*

Polyplax spinulosus Burmeister.

The sides of the abdominal segments are acute, but the males do not have the large tooth-like projection of *Hoplopleura.* The last segment of the female is truncate; the head is about as broad in front as behind, and the legs are very short and stout; the antennæ are as long as head, and the last joint is but little smaller than the others. Color, pale yellowish. Length, 1.4 millimeters.

This is the common rat louse, and is probably as widely distributed as its host. Specimens have been taken in both the eastern and western parts of the United States.

Polyplax miacantha Speiser.

This differs from *P. spinulosus* in having a longer and narrower anterior part of head, in that the last joint of the antennæ is more slender, and the antennæ are only two-thirds as long as the head. The abdominal segments 4 to 7 show an acute process at the sides. Length, 1.5 to 1.75 millimeters.

Taken from rats in Abyssinia.

MITES—ACARINA.

The mites (order Acarina, class Arachnida) are readily known from the insects (fleas and lice) by having four pairs of legs, no antennæ, and the abdomen does not show any segmentation, nor is there usually any distinction between head and thorax. In some groups there is a small head-like part, called the capitulum. The mouth parts consist of a pair of mandibles (often styliform or needle-like), a lip, and a pair of palpi. In some forms there is a central piece, called the hypopharynx, and in other groups is a plate above the mouth parts, known as the epistome. The body usually shows more or less distinctly a division into two parts—the anterior, called the cephalothorax, and the posterior the abdomen. However, in many mites it is not possible to separate these parts, except that it is considered that the legs are borne by the cephalothorax. In many forms there is a small, simple eye each side on the cephalothorax, but many other forms are blind. Some species have a tracheal system, which opens in a pair of spiracles near the hind legs or near the anterior end of the body; other species have no definite respiratory system. The genital aperture is on the venter, usually between the legs. The legs consist of the usual joints—coxa, trochanter, femur, tibia, sometimes a metatarsus, and a tarsus. The tarsus terminates in a pair of claws, sometimes three or only one, and often a sucker or caroncle. Most mites are not parasitic; those species that are parasitic are often free in one stage. The parasitic mites suck the blood of their host, feed on the hair or dermal scales, or burrow in the skin. Some predaceous species inhabit animals to hunt and eat the parasitic mites that infest that animal.

The mites that occur parasitically on rats belong to four families: Sarcoptidæ, Cheyletidæ Ixodidæ, and Gamasidæ.

1. A distinct spiracle or breathing pore on each side of body near coxæ III or IV...... 2
   No such spiracle or pore visible.. 3
2. A small, distinct head part in front of the body; palpi three jointed; a granulate area around the spiracle; no sternal plate.............................. *Ixodidæ.*
   No such head part; palpi five jointed; no granulate space around spiracle, but a long, chitinized piece reaching forward from it; a more or less distinct sternal plate.. *Gamasidæ.*
3. All legs simple, unmodified, ending in a stalked sucker............ *Sarcoptidæ.*
   Front legs short, enlarged, and modified for clasping; all legs end in one or two stout claws.. *Cheyletidæ.*

IXODIDÆ.

The Ixodidæ, or ticks, are rather large, flat, leathery-skinned mites, which suck the blood of various animals. In the male the dorsum of the body is nearly covered by a corneous shield, while in the female this shield occupies only the anterior part of the body. In the female the body swells to enormous proportions as she engorges herself on the blood of the host. At the posterior margin of the body there are in many forms a series of lobes or festoons. There is no species of tick that is commonly found on rats, but four species that normally infest other animals have been taken from them.

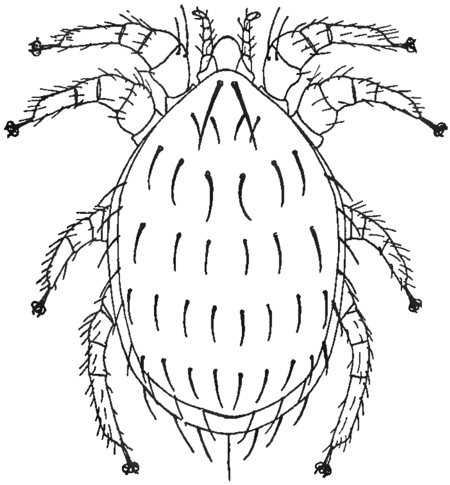


FIG. 8.—Mite (*Lælaps echidninus*).

1. On the venter is a groove in front of the anus and extending back each side; no festoons to posterior margin of body; palpi rather long........... *Ixodes ricinus.*
   On the venter there is no groove in front of the anus, but usually one behind; festoons distinct in males and unengorged females........................... 2
2. Palpi very short with transverse ridges; shield of female narrowed behind eyes; stigmal plate nearly round............................ *Margaropus annulatus.*
   Palpi short, without transverse ridges; shield of female not narrowed behind eyes; stigmal plate comma shaped......................... *Rhipicephalus sanguineus.*
   Palpi elongate, without ridges; shield of female broad; stigmal plate oval, *Hyalomma aegypticum.*

Ixodes ricinus Linné.

The shield of the female is elliptical, plainly longer than broad, sides not suddenly narrowed behind, and there is no eye-spot at each lateral corner. The coxa I has a long sharp spine.

This is a common European tick found on sheep, cattle, dogs, etc., and it has been taken a few times in this country. Neumann has recorded its capture from *Mus decumans.*

13429—10——6

Margaropus annulatus Say.

The shield is plainly longer than broad, with a distinct eye-spot at each lateral corner, and behind the eye the shield is suddenly narrowed; the coxæ of the female are without spines, but the male has 2 on coxæ I. This is the common cattle tick of the United States, and disseminates the Texas fever. Mr. Hunter has taken it once from a rat in a barn at Dallas, Tex.

Rhipicephalus sanguineus Latreille.

The shield of the female is oval, and longer than broad, with an eye-spot at each outer corner. Coxa I with 2 teeth; a smaller tooth on each of the other coxæ. Stigmal plate long, comma shaped. In the male there is a corneous plate each side of the anus, and on middle of posterior margin a projection, or short tail.

This species is common in tropical countries, and Nuttall has recorded specimens from the black rat in India.

Hyalomma aegypticum Linné.

The shield of the female is as broad as long, and the eye-spot is slightly above each outer corner. Coxa I has 2 large teeth, and a small tooth on each of the other coxæ. In the male there are 2 corneous plates each side of anus, and behind is a pair of small tubercles.

This is a common tick in the warmer parts of the Old World; and Nuttall has recorded young specimens on the black rat.

GAMASIDÆ.

The Gamasid mites, although much smaller than the ticks, are large enough to be seen by the naked eye. They are active, and most are not parasitic, at least for part of their time. The palpi are simple, of 5 joints; the mandibles are elongate, retractile, and usually chelate at tip. There are no eyes. The dorsum and often the venter shows one or more corneous shields or plates, frequently a number of them; one or two on the dorsum, and on the venter one between the coxæ, called the sternal plate; one behind this, the genital plate; one behind the latter, the ventral plate; and one surrounding the anus, the anal plate. Frequently some of these are absent or united to one of the others.

The legs are slender, usually of 6 joints, with a long tarsus that terminates in 2 claws, and often a sucker, or caroncle. The stigmata, or spiracles, are lateral above and between coxæ II and IV, and usually provided with a slender peritreme reaching forward toward the head. Nearly all the Gamasidæ deposit eggs, and the young often differ considerably from the adult in structure. There are two, and perhaps sometimes three, nymphal stages. In one of these nymphal stages the mite is apt to attach itself to an insect for the purpose of being carried to a similar locality, where it may feed and mature. The coprophagous and xylophagous insects are especially concerned in the diffusion of these mites.

There are, however, quite a number of species that are genuine parasites of insects and other animals. Those occurring on rats belong to two genera, Myonyssus and Laelaps. They can be separated as follows:

1. Anal plate small, much smaller than the ventral plate .... *Lælaps.*
   Anal plate large, larger than the ventral plate .... *Myonyssus.*

Myonyssus.—This genus is made by Tiraboschi for one species: *Myonyssus decumani* Tiraboschi.

Body oval; legs short and stout, all tarsi with a large caroncle with two short claws; coxæ II have a large tooth on the anterior border, none of coxæ with spines; sternal plate much broader than long, with three bristles each side; ventro-genital plate much longer than broad, broadest behind, bordered with bristles; anal plate very large, nearly one and a half times as broad as long; three large spines each side on venter. Length, 0.95 millimeter.

Found in Italy on *Mus decumans.*

Lælaps.—This genus embraces a large number of species, several of which occur on small animals, such as the muskrat, ground hog, and chipmunk. Three have been recorded from rats, one of these from California. The dorsal plate is covered with hairs or bristles, and there are usually stout bristles on the margins of the plates on the venter. There is also a bristle, or a spine, at the tip of the anal plate. The legs are short and stout, with a distinct caroncle, and two claws.

1. Dorsum with numerous fine hairs; no stout spines on coxæ......... *L. stabularis.*
   Dorsum with fewer, but stouter spine-like bristles; each coxa has a stout spine.... 2
2. Body but little longer than broad; ventral plate longer than broad...... *L. agilis.*
   Body much longer than broad; ventral plate about as broad as long.. *L. echidninus.*

Lælaps echidninus Berlese.

Dorsum of body almost wholly covered with a shield, with rows (six in front, eight behind) of stout, curved bristles, a longer pair near front margin, and some around lateral and posterior margins. Legs short and stout, tarsi about twice as long as preceding joint; each coxa bears a stout spine near middle. Palpi very short; sternum with three stout bristles or spines each side; ventral plate with four stout bristles each side; anal plate with a stout apical bristle, and a small one each side. Length, 1 millimeter.

Occurs commonly on rats in warm countries, and known from California. It may possibly aid in the transmission of disease.

Lælaps agilis Koch.

Similar in many respects to *L. echidninus* but differ in the shorter and proportionately broader body, barely longer than broad, and in the weaker and shorter spines on dorsum and on the ventral plates; there are also some small short spines on the general surface of the venter. Length, 0.7 millimeter.

Recorded from rats from Europe and Africa.

Lælaps stabularis Koch.

The body is of the same general shape as in *L. echidninus*, but the dorsum is clothed with 12 to 18 rows of fine short hairs. The first pair of legs is more slender than in the other species, and the hind legs are also more elongate; the coxæ do not have the stout spines seen in the other species, and the bristles on the sternal and ventral plates are much less stout; the general surface of the venter has many hairs, the anal plate has a short apical bristle. Length, 1.2 millimeters.

Taken on the brown rat in Italy; also found in manure.

CHEYLETIDÆ.

This family consists of small, soft-bodied mites, that are parasitic or predaceous in habits. The palpi are small, three or four jointed; the mandibles are styliform and retractile; and the breathing spiracles open near the mouth parts. The species that occur on rats belong to the genus *Myobia.*

Myobia.—The body is elongate, fully twice as long as broad, tipped by a pair of long, stout bristles. The first pair of legs is enlarged and shortened, with a terminal hook to grasp hairs; the other legs are short, simple, and far apart. The palpi and mouth parts are very small, and the dorsum bears stout bristles. They are supposed to feed on the exudations of the skin, but it would seem more probable, from the nature of the mandibles, that they pierced the skin to secure food. All are very small, not one-half a millimeter long. Of the several species two have been recorded from rats.

1. Dorsum of female with spines all acute and sharp.................. *M. musculi.*
   Dorsum of female with some of the posterior spines flattened and rather scale like.. *M. ensifera.*

Myobia musculi Schrank.

This occurs on various mice and moles, and once recorded from the brown rat. It has been taken in this country on mice. It lives at the base of the hairs.

Myobia ensifera Poppe.

This was described from the brown rat in Europe. The female is separated from *M. musculi* by having about six of the posterior dorsal spines flattened and scale like; in the male the six dorsal spines are longer, and the small spines much smaller than in *M. musculi.*

SARCOPTIDÆ.

These are the itch and scab mites. The body is soft, rounded, and whitish in color. The legs are very short, of five joints, and end in one or two claws, and often a pediceled sucker. The palpi are small and short, of three joints, but the basal is usually united to the rostrum. There are no spiracles, and respiration is therefore through the general surface of the skin. The sexes are often quite different in structure. The females usually deposit eggs, the larvæ are hexopod, and there are two nymphal stages. They are all parasites, mostly on mammals and birds, and often burrow in the skin, causing mange, or scabies.

Only one species has been taken on rats; this belongs to the genus *Notoedres*.

Notoedres.—In this genus the third pair of legs of the male and the third and fourth of the female have no sucker at the tip. The anal opening is on the posterior part of the dorsum. The three known species are parasitic on mammals—one on the cat, one on the rabbit, and the third on rats.

Notoedres muris Mègnin.

This is a rounded mite, with finely striate skin, a small triangular rostrum; in front the four anterior legs project a little beyond the body, and each ends in a long pedicellate sucker; the third and fourth pairs of legs are not visible from above, and each ends in a long bristle. There are a few short hairs around the anal aperture and about ten others in front of these. The species measures about 0.3 to 0.4 millimeter long.

It usually occurs about the ears and the genital organs of the host, and has been taken from both the brown and black rat in Europe. The *Sarcoptes alepis* Railliet and Lucet is the same species.

DEMODECIDÆ.

Besides the mites above described, a form of *Demodex* has been recorded from rats, but the species is not given. These mites are very tiny, with elongate body, the posterior part annulate, the front part with eight very short legs. They inhabit the hair follicles of various mammals. That on the rat may have been only an accidental occurrence of some species normally on another animal.

THE INTERNAL PARASITES OF RATS AND MICE IN THEIR RELATION TO DISEASES OF MAN.

By Ch. Wardell Stiles, *Chief*, and Charles G. Crane, B. S., *Assistant*, *Division of Zoology, Hygienic Laboratory, United States Public Health and Marine-Hospital Service.*

SUMMARY.

Rats and mice may harbor 11 species of internal parasites which come into consideration as possible or established parasites of man. From this point of view, 7 of the parasites are of more academic interest than practical importance. The rat may, however, be viewed as the practical, theoretical, and permanent reservoir for one zooparasitic disease (trichinosis) of considerable importance, and of at least one, perhaps two, other zooparasitic infections ("*Lamblia duodenalis*" and *Hymenolepis diminuta*) of much less importance. Its possible future rôle in connection with sleeping sickness should not be entirely ignored.

From the standpoint of internal zooparasitism, therefore, the present public health interest in rats and mice centers in trichinosis. This disease will probably never be eradicated from man until rats and mice are practically eradicated, and any rational public-health campaign directed against trichinosis must take the rat into serious consideration.

The eradication of rats and mice would be a very substantial contribution toward a reduction and eradication of trichinosis.

INTRODUCTION.

From the habits of rats, it is to be expected that they harbor many species of parasites, and on account of their presence in our houses the question naturally arises as to whether any of these parasites are transmissible, either directly or indirectly, to man.

The species of internal parasites which come especially into consideration in this connection are the following:

Protozoa: *Chlamydophrys enchelys* (p. 88), *Lamblia duodenalis* (p. 89), *Trypanosoma gambiense* (p. 94).

Trematoda: None.

Cestoda: *Cysticercus cellulosæ* (p. 95), *C. fasciolaris* (p. 96), *C. pisiformis* (p. 95), *H. murina* Duj. [=*fraterna*] (p. 96), *Hymenolepis diminuta* (p. 98).

Nematoda: *Trichinella spiralis* (p. 101).

Acanthocephala: *Gigantorhynchus moniliformis* (p. 108).

Arachnoidea: *Linguatula denticulata* (p. 110).

Of these 11 species, the trichina worm (sometimes called the flesh worm) exceeds all the others combined, both in frequency and importance, as a cause of disease in man.

PROTOZOA.

Genus CHLAMYDOPHRYS[a] Cienkowski, 1876.

Species CHLAMYDOPHRYS ENCHELYS[b] (Ehrenberg.)

A very peculiar organism has been described under the name of *Leydenia gemmipara* Schaudinn, 1896. This was found in fluid, obtained by puncture, from two ascites patients in Berlin, Germany. More recently Schaudinn has concluded that *Leydenia gemmipara* represents an abnormal condition of a protozoon known as *Chlamydophrys*. The latter passes through the intestinal tract of various animals (as man, mice, squirrels, rabbits, cattle), and thus is occasionally found in fresh human stools. According to Schaudinn, if pathological conditions in the colon cause an alkaline reaction of its entire content, the usual shell formation in *Chlamydophrys* fails to take place, the organisms then multiply in an atypical manner by division and budding, and the result is the structure described as *Leydenia gemmipara*.

Genus LAMBLIA[c] R. Blanchard, 1888.

GENERIC DIAGNOSIS.—*Polymastigidæ:* Body bilaterally symmetrical, pyriform, excavate antero-ventrally to form a sucker; flagella directed posteriorly; 3 pairs inserted on margin of the sucker, 1 pair at posterior end of body. Parasitic in intestine of mammals.

TYPE SPECIES.—*Lamblia duodenalis* s. l. ("*L. intestinalis*" of man).

Flagellate protozoa belonging to this genus are reported as parasitic in the intestinal canal of various species of mammals. At present the forms in question are usually looked upon as belonging to the species *L. duodenalis*. Evidence is, however, accumulating (p. 92) to the effect that there are at least three distinct species of *Lamblia* ("*L. intestinalis*" of man, *L. muris* of mice, and *L. cuniculi* (or *duodenalis*?) of rabbits). Admitting that there may be three species, the intertransmissibility of these forms from one host to another remains to be investigated to some extent. It seems thus far definitely proved that the form which occurs in man is transmissible to mice, rabbits, and guinea pigs, hence mice still remain a source of danger in respect to the infection in man. To exactly what extent this fact is of academic interest or of practical significance is at present *sub judice*.

---

[a] SYNONYM.—*Leydenia* Schaudinn, 1896.

[b] SYNONYMS.—*Difflugia enchelys* Ehrenberg; *Chlamydophrys stercorea* Cienkowski; *Leydenia gemmipara* Schaudinn, 1896; *Chl. enchelys* (Ehrenberg) Braun.

[c] SYNONYMS.—*Dimorphus* Grassi, 1879 (not Haller, 1878, arachnoid); *Megastoma* Grassi, 1881 (not de Blainville, mollusk; not Swains., 1837, bird; not Costa, 1850, fish; not Megerle, mollusk); "*Dimorpha* Grassi" of Senn, 1901 (not *Dimorpha* Jur., 1807, hymenopteron; not Gray, 1840, mollusk; not Hodgs., 1841, bird); *Megastroma* Schneidemuehl, 1898, misprint.

Species LAMBLIA DUODENALIS [a] (Davaine, 1875) Stiles, 1902, s. l.

[Figs. 9 to 15.]

SPECIFIC DIAGNOSIS.—*Lamblia* (p. 88): Body pyriform, 5 to 16μ (21μ Lambl) long, 4 to 12.5μ (8.6 to 11μ Lambl) broad; flagella 9 to 14μ long; anterior end bluntly rounded, posterior end sharply pointed, dorsum convex, antero-ventrally concave, venter flat to convex; antero-ventral concavity forms a sucker, the margins of which project from the surface and are contractile. Four pairs of ventral posteriorly directed flagella, arranged as follows: 1 pair insert on anterior margin of sucker; 2 pairs on posterior margin of sucker, near median line; 1 pair on posterior extremity. Body membrane ("cuticula") very delicate, permitting some change of body form; protoplasm finely granular; nucleus dumb-bell shaped, pre-equatorial. Vacuoles not observed. Copulation sucker-to-sucker, followed by an encystation, in which stage complicated nuclear changes occur; cysts 10 by 7μ.

HABITAT.—Upper portion of small intestine of man (*Homo*); also of the common house mouse (*Mus musculus*), the brown rat (*M. decumanus*), the black rat (*M. rattus*), "*Mus sylvestris*" [=? *M. decumanus*], field mouse (*Microtus arvalis*), water mole (*Arvicola amphibius*), rabbits, guinea pigs, domesticated cats, dogs, and sheep.

GEOGRAPHICAL DISTRIBUTION.—Europe, Egypt, and United States.

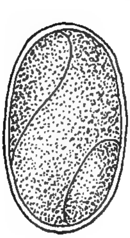
This parasite is very common in animals in certain parts of Europe, and cases of its presence in man have been reported by a number of authors (Lambl, 1859; Grassi, 1881; Perroncito, 1888; Moritz, 1891; Moritz & Holzl, 1892; Roos, 1893; Kruse & Pasquale, 1894; Piccardi, 1895; Sievers; Mueller; Frshezjesski & Ucke; Stiles, 1902; Braun, 1908; etc.). The indications are that it is more common in man than is generally assumed.

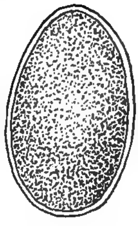
Possibly man becomes infected through eating food (as bread, etc.) which has been soiled by the excrements (containing the encysted stage) of mice and rats. Grassi infected himself, Perroncito infected mice and rabbits, and Stiles infected guinea pigs by feeding to them human feces containing the encysted stage.

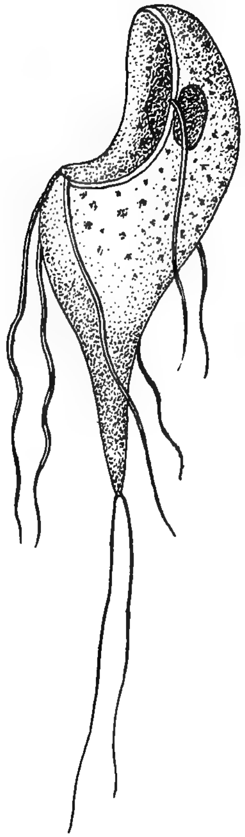
The parasite may be present in large numbers. Moritz estimated a discharge of 18 milliards within twenty-four hours from one of his patients. It has been observed in healthy persons and also in cases of various diseases, but especially in children and in cases of tuberculosis. It is an inhabitant chiefly of the duodenum and jejunum, where it attaches itself (fig. 13) by means of the sucker to the epithelial cells. It is rarer in the ileum. In case the stomach is alkaline (carcinoma) the parasite may occur in this organ (Cohnheim, Zabel). In P. Schmidt's case the hydrochloric acid was 1 per cent. In case the intestinal peristalsis is normal the parasite

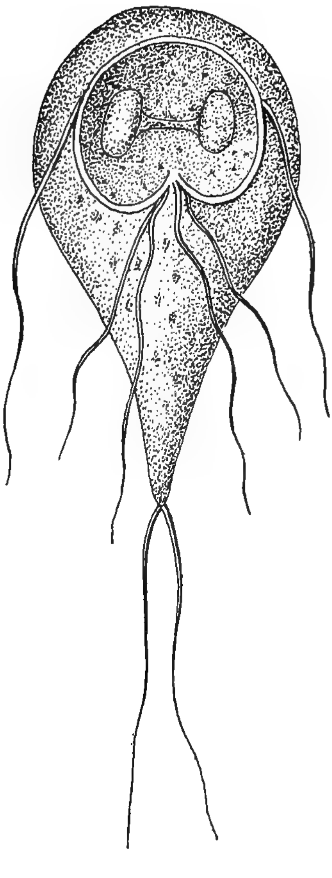
---

[a] SYNONYMS.—*Cercomonas intestinalis* Lambl, 1859, in man (not *Bodo* (*Cercomonas*) *intestinalis* (Ehrenberg, 1838) Diesing, 1850, in frogs; not *Cercomonas intestinalis* (Ehrenberg, 1838) Perty, 1852); *Hexamita duodenalis* Davaine, 1875, in rabbits; *Dimorphus muris* Grassi, 1879, in *Mus; Megastoma entericum* Grassi, 1881 (=*Dimorphus muris* renamed); *Megastoma intestinale* (Lambl, 1859) R. Blanchard, 1885; *Lamblia intestinalis* (Lambl, 1859) R. Blanchard, 1888; "*Megastoma intestinalis*" of Leclerq, 1890; "*Cercomonas intistinalis* Lambl" of L. Pfeiffer; "*Megastroma entericum* Grassi, 1881" of Schneidemuehl, 1898; "*Dimorpha muris* Grassi" of Senn, 1900.









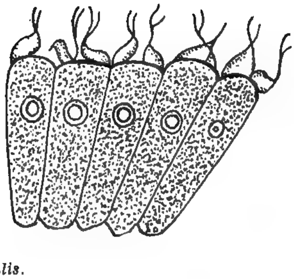


FIG. 9.—Lateral view of encysted *Lamblia duodenalis*.
FIG. 10.—Cyst from large intestine.
FIG. 11.—Ventral view of *Lamblia*.
FIG. 12.—Lateral view.
FIG. 13.—Epithelial cells of the villous coating of the small intestine infested with *Lamblia*. (After Grassi & Schewiakoff, 1888, pl. 15, figs. 1, 2, 5, 11, 12.)

becomes encysted in the colon, so that usually only the encysted stage is found in the feces; but in case of increased peristalsis and diarrhea the organisms have not time to encyst, so that the free stages are observed in the stools. As the parasites become cool motion decreases; when raised to high temperature, as 50° C., motion becomes slow, and the organisms die at 52° C. or below 0° C.

PATHOGENICITY.—Opinion differs as to the pathogenicity of this organism. Perroncito (1902b) reports it as causing a fatal disease in rabbits. Braun (1908) is inclined to consider it harmless. From

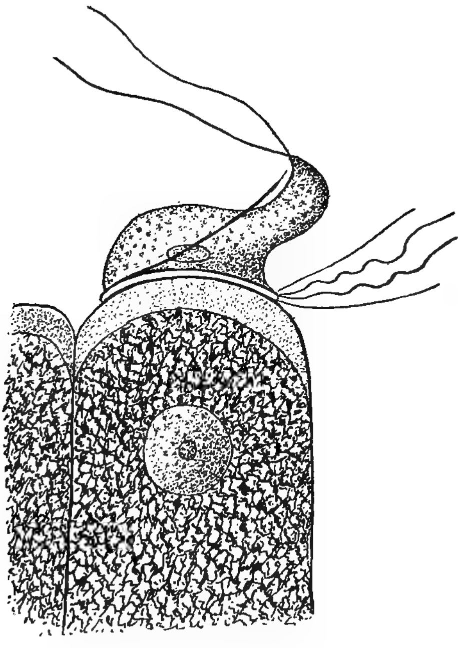


FIG. 14.—An epithelial cell with parasitic *Lamblia*. Greatly enlarged. (After Grassi & Schewiakoff, 1888, pl. 15, fig. 6.)

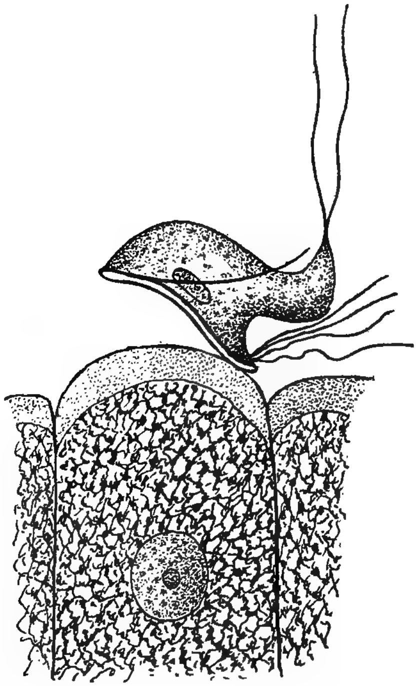


FIG. 15.—An individual in the act of joining an epithelial cell. (After Grassi & Schewiakoff, 1888, pl. 15, fig. 7.)

conversation with Doctor Hemmeter, we are persuaded that in his case in a child in Baltimore the parasite was not without effect. Possibly the question as to its pathogenicity is a relative one in that light infections may produce no recognizable disturbance, while heavy infections may produce recognizable effects. Doctor Hemmeter's original letter regarding his case contained the following notes:

Patient, male, white child, 3 years old, born in Maryland. Had recurrent attacks of colitis all its life; three acute attacks within the last three weeks, accompanied by fever, distended abdomen, sensitive, etc. Stools have always been like putty, containing large amount of mucus, and some blood streaks; fever lasting three days, no pronounced diarrhea, 2 to 3 passages per day; intervals between attacks variable, stools at such times like putty, also with mucus.

Later information from Doctor Hemmeter states that the disappearance of the parasites from the stools coincided with improvement in the child's condition.

Clinical diagnosis.—The fresh unstained stools should be examined microscopically; or the diluted stool may be stained with methylene blue, by which nearly all objects become promptly stained, except *Lamblia*, which remains grayish white (Roos, 1893) for several hours.

Treatment.—Attempts to expel *Lamblia* have not always met with marked success. Among the drugs used are male fern, sulphate of quinine, naphthol, calomel, hydrochloric acid, and arsenic. Grassi appears to have had success with calcined magnesia.

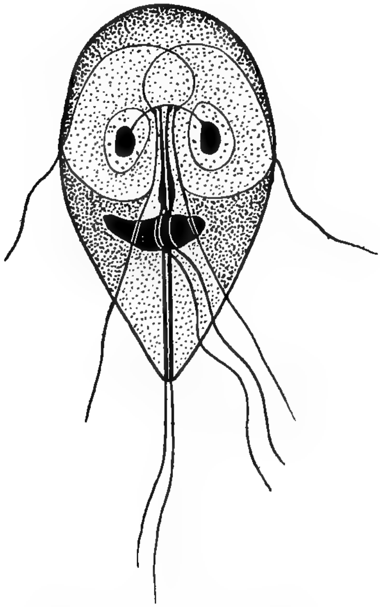


Fig. 16.—"*Lamblia intestinalis*" of man. (After Bensen, 1908, fig. 5.)

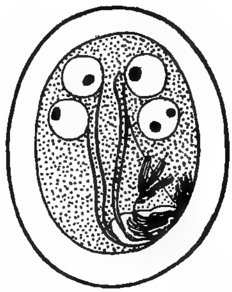


Fig. 17.—Copulation cyst of "*Lamblia intestinalis*" of man. (After Bensen, 1908, fig. 5.)

The division of *Lamblia duodenalis* into separate species.—Bensen (1908) has recently divided *Lamblia duodenalis* s. l. into three species: *L.* "*intestinalis*," *L. muris*, and *L. cuniculi*. His preliminary paper seems to offer fairly convincing data for the correctness of his interpretation, but it may be well to await the publication of his more complete paper, in which he promises fuller details, before the species are definitely accepted. Several nomenclatural points will come up for consideration in this connection.

Lamblia intestinalis, which Bensen accepts as name for the species (fig. 16) occurring in man, can not be accepted, as this name is based on *Cercomonas intestinalis* Lambl, 1859, which is invalidated by

Cercomonas intestinalis (Ehrenberg, 1838) Perty, 1852, found in frogs.

Lamblia muris (fig. 18) will probably stand, based on *Dimorphus muris* Grassi, 1879.

Lamblia cuniculi.—There is some doubt as to the status of this name. Davaine (1875a, 128–129) has described from rabbits a protozoon, which he designated as *Hexamita duodenalis* and which Railliet (1893a, 169) identifies as a synonym of *Lamblia intestinalis* (Lambl). On basis of the principle that identifications are to be accepted as correct until shown to be incorrect, Stiles has accepted *duodenalis* as name (1902) for the form in question. The question now arises as to the relation of *cuniculi* to *duodenalis*. If they are accepted as identical, *duodenalis* will supplant *cuniculi*, and a new

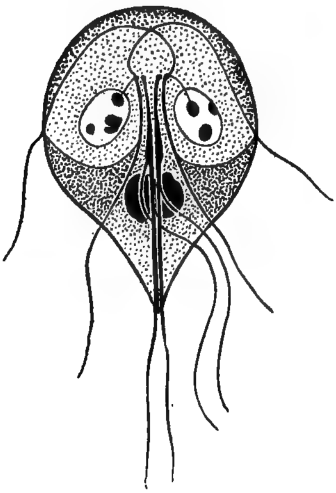


FIG. 18.—*Lamblia muris* of mice. (After Bensen, 1908, fig. 1.)

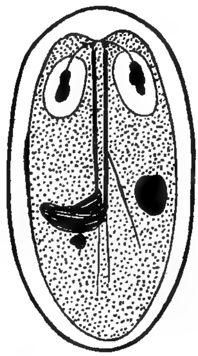


FIG. 19.—Autogametocyte of *Lamblia muris*. (After Bensen, 1908, fig. 6.)

name must be given to the form found in man. If *duodenalis* is taken as identical with *intestinalis* Lambl, *duodenalis* remains as name for the form in man, and *cuniculi* Bensen will stand for the species in rabbits. If Railliet's interpretation of synonymy be shown to be incorrect by proving that *duodenalis* Davaine is not to be considered in connection with either form, a new name must be given to *intestinalis* Lambl.

Genus TRYPANOSOMA s. l.

An extensive group of parasitic protozoa, known as "trypanosomes," has recently been the basis of considerable literature. The genus *Trypanosoma* was originally based upon a species (*T. rotatorium*) found in frogs, and while most trypanosomes have been described as members of this genus several authors have separated out certain forms into separate genera.

Luehe (1906) has recently placed the trypanosomes of mammals in the

Genus TRYPANOZOON Luehe, 1906.

One of these species (*Trypanozoon gambiense*, usually known as *Trypanosoma gambiense*) is the cause of "sleeping sickness" in man, and has been transmitted in laboratory experiments to rats and mice.

Just what practical importance there may be in the ability of the

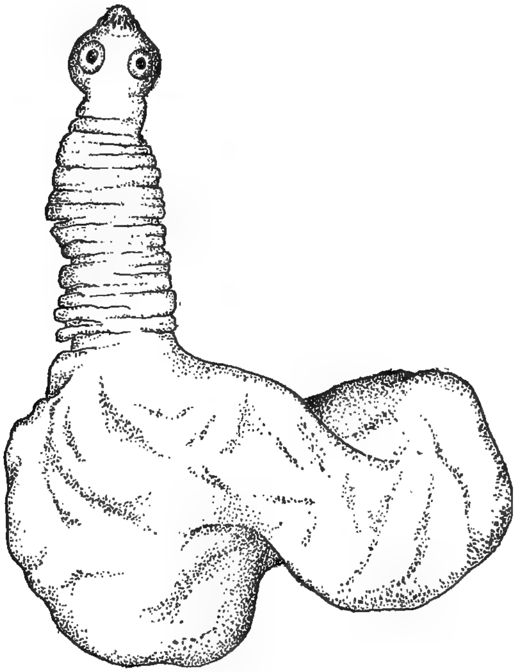


FIG. 20.—An isolated pork-measle bladder worm (*Cysticercus cellulosae*), with extended head. Greatly enlarged. (After Stiles, 1898a, 90, fig. 76.)

parasite to live in rats and mice remains to be seen, but theoretically this biological factor may possibly become one of considerable magnitude. At present the least conclusion to be drawn is that it adds one more to the many arguments in favor of a world-wide destruction of rats and mice.

Several trypanosomes, other than *Trypanozoon gambiense*, are transmissible by experiment to rats and mice, while one species (*Trypanozoon lewisi*) has rats for its normal host, and two other species (*Trypanozoon duttoni* and *Trypanosoma musculi* Kendall, 1896) are reported originally from the mouse.

CESTODA—TAPEWORMS.

Of the five cestodes mentioned as coming into consideration in the subject under discussion, only one (*Hymenolepis diminuta*) need be considered seriously.

CYSTICERCUS CELLULOSÆ—TÆNIA SOLIUM.

[Fig. 20.]

The larval cestode known as *Cysticercus cellulosæ* (which causes "measles" in swine) develops (when eaten by man) into a tapeworm which is known as *Tænia solium.* This larva is also reported as encysted in the peritoneum of *Mus rattus.*

Even if it be granted that the specific determination of the specimen in question as *Cysticercus cellulosæ* is correct, the occasional infection of rats with this parasite would be of very little practical significance

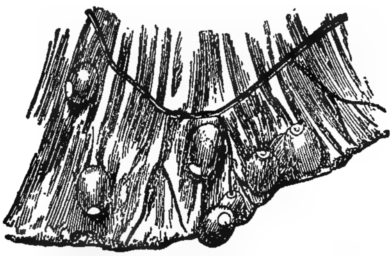


FIG. 21.—Portion of mesentery of rabbit infected with *Cysticercus pisiformis.* Natural size. (After Railliet, 1893a, 216, fig. 114.)

in this country from a public health point of view, as we do not use rats for food for man. Theoretically it is possible to conceive of combinations of circumstances in which such infection in the rat might under certain conditions eventually affect man, but the chances are so remote as to be negligible, especially when compared with the much greater questions which demand attention.

CYSTICERCUS PISIFORMIS—TÆNIA PISIFORMIS.

[Fig. 21.]

The larval stage of this parasite occurs in rabbits, the adult stage in canines. Parona (1901) reports the occurrence of the larval stage in *Mus brasiliensis,* and Vital has recorded the presence of the adult stage in man.

In view of the fact that Galli-Valerio was unable to infect himself experimentally with this species, the specific determination made by Vital is open to some question. Even assuming that this tapeworm may develop in man, the presence of the larval stage in rats is of such little importance as to be negligible.

CYSTICERCUS FASCIOLARIS TÆNIA TENIÆFORMIS.

[Fig. 22.]

This encysted larval tapeworm is exceedingly common in the liver of rats and mice, and when swallowed by cats it develops into an adult tapeworm.

There are two possible points of view in connection with which this parasite is of indirect interest in public-health matters: (1) Occasionally these encysted parasites are mistaken for lesions of tuberculosis; (2) Krabbe (1880) relates that in Jutland there exists a folk custom of eating chopped raw mice in case of retention of urine, and in this connection the point has been raised that the possibility is not excluded that such action might eventually give rise to infection of

FIG. 22.—Larval stage of *Tænia teniæformis*. Natural size. (After Leuckart, 1880, 450, fig. 202.)

man by the parasite in question. No case of such infection in man is as yet established.

HYMENOLEPIS MURINA[a] (Dujardin, 1845)=HYMENOLEPIS NANA FRATERNA[a] Stiles, 1906.

[Figs. 23 and 24.]

Under the name *Tænia murina*, Dujardin (1845) described for rats a tapeworm which has been identified by a number of authors (including Stiles) as identical with the dwarf tapeworm (*Hymenolepis nana*) of man. If this identification be correct, the rats must be considered as the great disseminators of this tapeworm. Serious doubts have been raised, however, as to whether the tapeworm in man is not in reality distinct from that of the rat, and the evidence in favor of such conclusion is accumulating. Some slight differences between the two forms have been noticed, but by some authors these differences have

[a] SYNONYM.—*Tænia murina* Dujardin, 1845 (not Gmelin, 1790).

been considered insufficient to hold the two worms apart. Looss has tried to infect rats with the dwarf tapeworm found in man in Egypt, but his results have been negative. Here in Washington Stiles has repeatedly attempted to infect rats with the dwarf tapeworm found in man in the United States, but thus far no positive infection has occurred in the rodents. In Italy, Grassi attempted to transmit the rat form to six persons, and in one case he found tapeworms, but in view of the frequency of *H. nana* in Italy the significance of this one

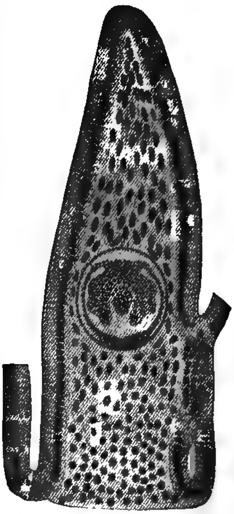


FIG. 23.—Longitudinal section of the intestinal villus of a rat, containing cystic stage of dwarf tapeworm. Enlarged. (After Grassi & Rovelli, 1892a, pl. 3, fig. 25.)

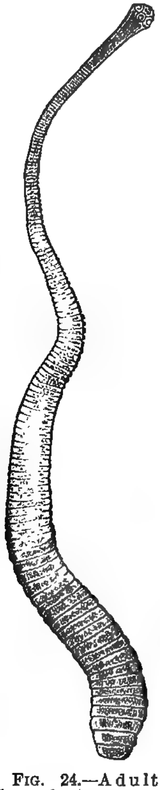


FIG. 24.—Adult dwarf tapeworm (*Hymenolepis nana*) of man. Enlarged. (After Leuckart, 1863, p. 393, fig. 112.)

instance has been questioned; Grassi was not successful in trying to infect rats with *H. nana* of man.

Thus at present the evidence is to the effect that rats and mice are not to be viewed as the source or reservoir for the dwarf tapeworm (*H. nana*) of man.

13429—10——7

HYMENOLEPIS DIMINUTA [a] (Rudolphi, 1819) R. Blanchard, 1891.

[Figs. 25 to 30.]

SPECIFIC DIAGNOSIS.—*Hymenolepis:* Strobila 10 to 60 millimeters in length, 2.5 to 4 millimeters in maximum breadth; composed of 800 to 1,300 segments. Head small, almost globular; 200 to 600μ in width; rostellum rudimentary, pyriform, only slightly

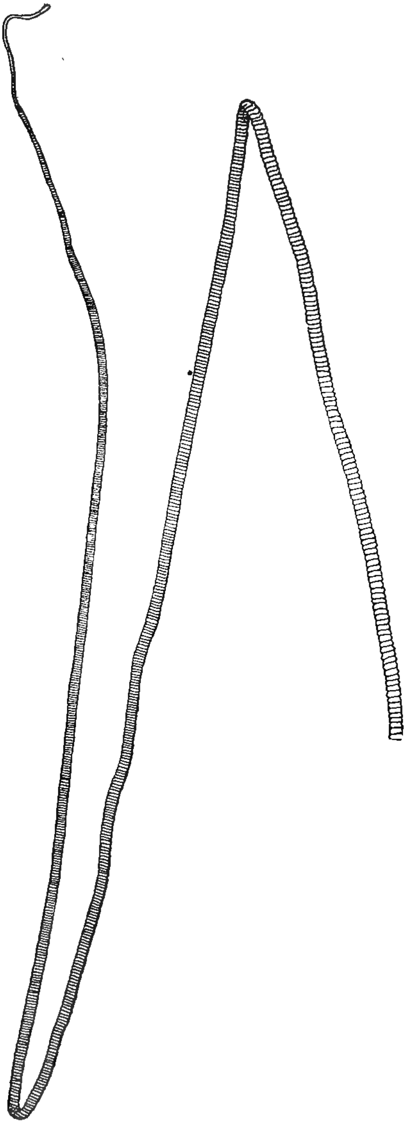


FIG. 25.—Strobila of *Hymenolepis diminuta.* Natural size. (After Grassi, 1881, pl. 11, fig. 1.)

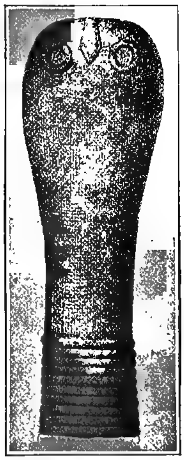


FIG. 26.—Head and anterior portion of *H. diminuta* from the rat. Enlarged. (After Zschokke, 1889, pl. 1, fig. 21.)

---

[a] SYNONYMS.—*Tænia diminuta* Rudolphi, 1819; *T. leptocephala* Creplin, 1825; *Hymenolepis flavopunctata* Weinland, 1858; *Tænia (Hymenolepis) flavopunctata* Wein-

protractile; hooks absent; suckers globular, near the apical portion of the head, 80 to 160μ in diameter. Neck usually short. Segments throughout strobila broader than long. Genital pores on left margin, near the junction of the anterior and middle thirds of each segment. Three testes in each segment; vas deferens dilates into a prominent seminal vesicle before entering the cirrus pouch, within which also is a vesicle. Gravid uterus occupies most of the proglottids; its cavity is subdivided into a large number of incompletely separated compartments filled with eggs. Eggs round or slightly oval; outer membrane 54 to 86μ in diameter, yellowish in color, may be radially striated; inner membrane 24 by 20μ to 40 by 35μ in diameter, with mammillate projection at each pole often not apparent; between outer and inner membranes a prominent third layer of albuminous substance, often appearing as two delicate smooth membranes, with intervening space filled by a granular coagulum; embryonal hooks 11 to 16μ in length.

HABITAT.—Adults in small intestine of brown or Norway rat (*Mus decumanus*), black rat (*M. rattus*), house mouse (*M. musculus*), Egyptian or roof rat (*M. rattus alexan-*

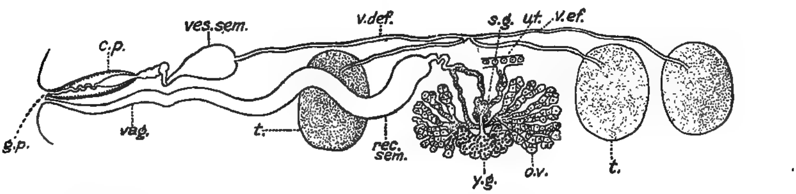


FIG. 27.—Male and female organs of *H. diminuta: c. p.*, cirrus pouch; *g. p.*, genital pore; *ov.*, ovary; *rec. sem.*, receptaculum seminis; *s. g.*, shell gland; *t.*, testiculæ; *ut.*, uterus; *vag.*, vagina; *v. def.*, vas deferens; *v. ef.*, vas efferens; *ves. sem.*, vesicula seminalis; *y. g.*, yolk gland. Enlarged. (After Zschokke, 1889, pl. 2, fig. 22.)

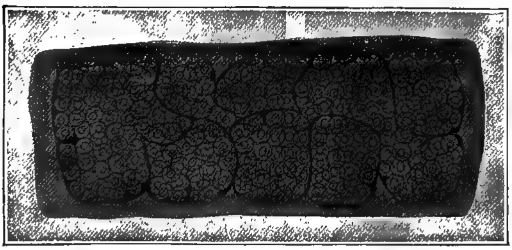


FIG. 28.—Gravid segment of *H. diminuta.* Enlarged. (After Grassi, 1881, pl. 11, fig. 15.)

FIG. 29.—Egg of *H. diminuta* from man. Greatly enlarged. (After Bizzozero, 1889a, pl. 4, fig. g″.)

drinus), wood or field mouse (*M. sylvaticus*), *Rhipidomys pyrrhorhinus* [according to Linstow, 1878a, 23], and man (*Homo sapiens*).

---

land, 1859; *H.* (*Lepidotrias*) *flavopunctata* Weinland, 1861; *T. flavomaculata* Leuckart, 1863; *T.* "*flavopuncta*" Cobbold, 1864 (misprint); *T.* "*flaviopunctata*" Vogt, 1878 (misprint); *T.* "*flavopunktata*" Stein, 1882; *T. varesina* E. Parona, 1884; *T. minima* Grassi, 1886; *T.* "*septocephala*" Perroncito and Airoldi, 1888 (misprint); *Hymenolepis diminuta* (Rudolphi, 1819) Blanchard, 1891; "*Hymenolepsis*" *flavopunctata* of Osler, 1895, and other authors (misprint); *T.* "*varerina*" Huber, 1896 (misprint for *T. varesina*); *T.* "*flavapunctata*" Simon, 1896 (misprint); *T.* "*leptocefala*" Previtera, 1900; *T.* "*ceptocephala*" Lussana and Romaro [? date] (misprint); *Tenia flavopunctata* (Weinland, 1858) Packard, 1900.

Development.—The larval stage (*Cercocystis H. diminutæ*) occurs in larval and adult meal moths (*Asopia farinalis*); in young and adult earwigs (*Anisolabis annulipes*); and in adult beetles (*Acis spinosa* and *Scaurus striatus*).

Geographic distribution.—Massachusetts, Pennsylvania, Nebraska, Iowa, District of Columbia, Maryland, Brazil, Italy, Germany, France, Austria.

This parasite is certainly more common in man in this country than has heretofore been assumed, but fortunately it seems to be one of the most harmless and most easily expelled tapeworms occurring in man.

From present evidence, the rats and mice are looked upon as the

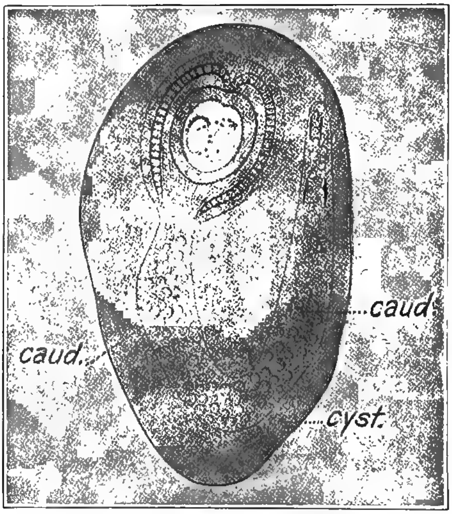


Fig. 30.—Encysted cystic stage of *H. diminuta: caud.*, caudal appendage; *cyst.*, adventitious capsule inclosing the cercocystis. Enlarged. (After Grassi & Rovelli, 1892a, pl. 4, fig. 1.)

regular hosts for this worm, and hence as the natural reservoir of the infection. The intermediate host becomes infected from the rodents and then transmits the infection to man.

It might be mentioned that as yet no extensive study has been conducted in the United States to differentiate clearly the various species of *Hymenolepis* found in our rats and mice. The possibility is therefore not entirely excluded that some of our cases of *Hymenolepis diminuta* may eventually be shown to be referable to other species of the same genus.

NEMATODA—TRUE ROUND WORMS.

Family TRICHINELLIDÆ.[a]

FAMILY DIAGNOSIS.—*Nematoda:* Elongate cylindrical worms; cephalic portion long and very slender, caudal portion more or less swollen. Mouth rounded, without lips. Esophagus relatively very long, composed of a single row of large cells, forming the so-called "cell body" and supporting a narrow esophageal tube; anus terminal or nearly so.

Male: With a single spicule or without spicule.

Female: With one ovary; vulva near caudal end of cell body, close to point where body increases in diameter; oviparous or viviparous.

Eggs: Oviparous species, with thick shell, with opening at each pole, closed by a transparent plug.

TYPE GENUS.—*Trichinella* Railliet, 1895.

This family furnishes two parasites to man: The whipworm (*Trichuris trichiura*) of the colon, and the trichina or flesh worm (*Trichinella spiralis*, see p. 101).

Genus TRICHINELLA[b] Railliet, 1895.

GENERIC DIAGNOSIS.—*Trichinellidæ:* Very minute worms, of nearly uniform diameter. Adults in intestine of mammals, larvæ encysted in muscles.

Male: Without spicules, but with 2 conical appendages on the tail, at side of terminal cloacal opening.

Female: Vulva about one-fifth the length from anterior end; viviparous.

TYPE SPECIES.—*Trichinella spiralis* (Owen, 1835) Railliet, 1895.

TRICHINELLA SPIRALIS (Owen, 1835) Railliet, 1895.

[Figs. 31 to 51.]

SPECIFIC DIAGNOSIS.—*Trichinella:* Body thread-like, visible to naked eye.

Male: Length, 1.4 to 1.6 millimeters; diameter, 40μ; distal of cloacal opening, 2 pairs of papillæ, the anterior pair hemispherical, posterior pair conical.

Female: Length, 3 to 4 millimeters; diameter, 60μ; anus terminal; vulva one-fifth of length of body from the mouth; viviparous.

HABITAT.—Adults in lumen and wall of small intestine, encysted larvæ in muscles of various mammals, particularly in rats, mice, swine, and man.

GEOGRAPHIC DISTRIBUTION.—More or less cosmopolitan.

SOURCE OF INFECTION.—From the life cycle of this parasite it is clear that the permanent reservoir of infection must be some animal with cannibalistic tendencies. Of the three most important hosts (man, swine, and rats), the rats present ideal conditions in this respect. It is true that there are some tribes of man which are cannibalistic, but their distribution is restricted. Likewise swine are in so far cannibalistic that they eat uncooked swine offal and swill, but this is due to the shortsightedness of man rather than to

---

[a] SYNONYM.—*Trichotrachelidæ.* It becomes necessary under the international code to change the family name; the family name *Trichinellidæ* is chosen as less likely to lead to confusion than a family name based upon *Trichuris.*

[b] SYNONYMS.—*Trichina* Owen, 1835 [not Meig., 1830, insect.]; *Trichinus* Fraser, 1881a, for *Trichina.*

the habits of the swine. Accordingly, neither man nor the hog presents the proper theoretical conditions for the perpetuation of the parasites and hence to serve as reservoir for the disease it causes.

Rats, on the contrary, are cannibalistic, and trichinosis is a common disease among them. Hence they may be viewed as the natural reservoir for the parasites and for the disease it causes; hence, also, any well-directed public health campaign against trichinosis should consider the eradication of rats.

Rats become infected by eating each other; by eating scraps of pork found on the offal pile of slaughterhouses, or in swill; and by eating scraps of human flesh in dissecting rooms of medical schools.

FIG. 31.—Female trichina from the intestine; 24 hours after infection. Enlarged. (After Leuckart, 1866a, pl. 1, fig. 1.)

Swine become infected by eating rats, and by eating scraps of pork on the offal pile of slaughterhouses, or in swill.

Man becomes infected almost exclusivly by eating pork and boar meat. The rare infections which occur from eating other meat are almost negligible.

MEDICAL SIGNIFICANCE.—*Trichiniasis* or *trichinosis* refers to infection with the trichina or flesh worm. Normally it occurs only in mammals, chiefly carnivorous and omnivorous species, and it is transmissible from any infected mammal to any other mammal susceptible to it, in case the latter eats the uncooked flesh of the former.

Symptoms.—In heavy infections there may be three more or less distinct periods of the disease, corresponding to the three stages in the life cycle of the parasite; but these stages are obscure in light or in repeated infections. Profuse sweating may last during the entire attack.

Period of ingression: The adult parasites are in the intestine, hence gastro-intestinal symptoms develop; irregular appetite, nausea, diar-

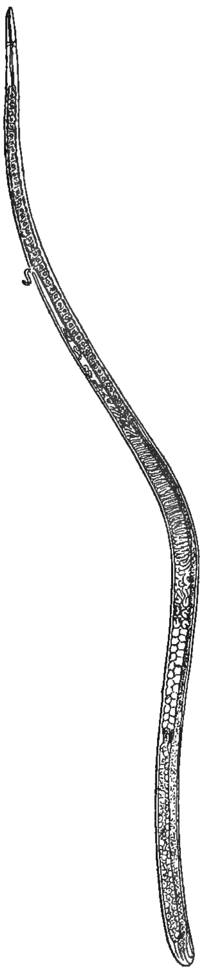


Fig. 32.

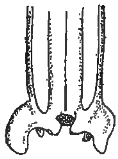


Fig. 34.

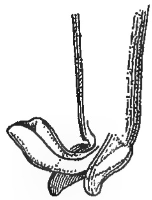


Fig. 35.

Fig. 37.

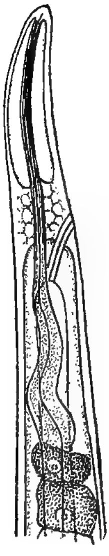


Fig. 36.

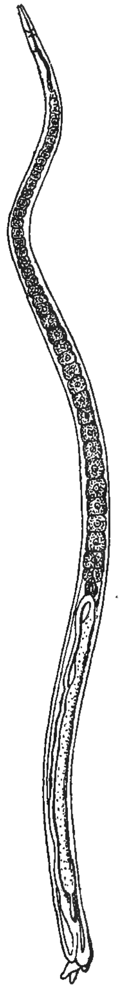


Fig. 33.

Fig. 38.

Fig. 32.—Gravid adult female trichina. Enlarged. (After Leuckart, 1866a, pl. 1, fig. 2.)
Fig. 33.—Adult male trichina from the intestine. Enlarged. (After Leuckart, 1866a, pl. 1, fig. 5.)
Fig. 34.—External genitalia of same. Enlarged. (After Leuckart, 1866a, pl. 1, fig. 7.)
Fig. 35.—The same with extruded cloaca. Enlarged. (After Leuckart, 1866a, pl. 1, fig. 8.)
Fig. 36.—Cephalic portion of a trichina showing central nervous system and anterior portion of intestinal canal. Greatly enlarged. (After Leuckart, 1866a, pl. 1, fig. 13.)
Fig. 37.—Transverse section of a female trichina. Greatly enlarged. (After Leuckart, 1866a, pl. 1, fig. 16.)
Fig. 38.—Young trichina embryo in a muscle fibre. Greatly enlarged. (After Leuckart, 1866a, pl. 2, fig. 1.)

rhea or constipation, colicky pains; a temporary edema around eyes about the eighth day; muscular pains begin.

Period of digression: This begins about the eighth to the fifteenth day, sometimes later; young embryos are wandering to and attacking the muscles, hence muscular symptoms (myositis) develop; painful tension of muscles, especially biceps; members assume semiflexed

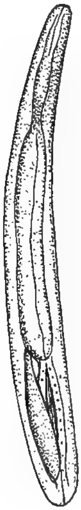


Fig. 43.

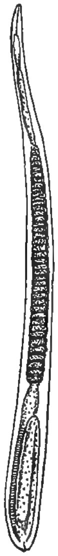


Fig. 45.

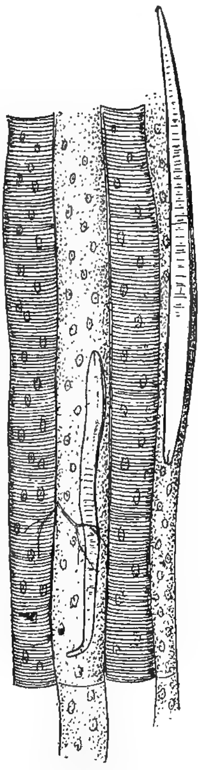


Fig. 41.

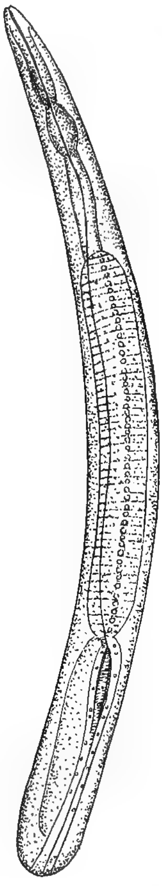


Fig. 44.

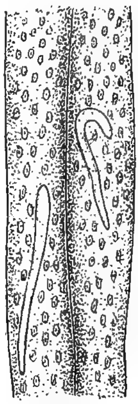


Fig. 40.

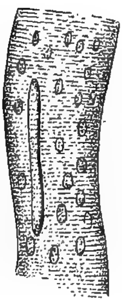


Fig. 39.

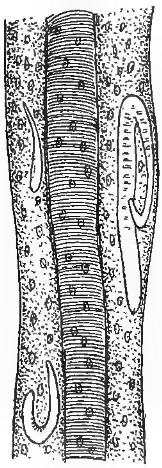


Fig. 42.

FIGS. 39–42.—Later stages of same; the muscular structure is undergoing changes. (After Leuckart, 1866a, pl. 2, figs. 3, 6, 7, 8.)

FIGS. 43–45.—Muscle trichinæ, 0.3 mm., 0.4 mm., and 0.6 mm. long. (After Leuckart, 1866a, pl. 2, figs. 10–12.)

position; movements, chewing, swallowing, breathing, and speech become difficult; eyes become fixed; fever.

Period of regression: The parasites become encysted in muscles. All symptoms may increase, then gradually decrease; cachexia and anemia resulting from malnutrition; pruritis, miliary cutaneous eruptions; desquamation; about twenty-fourth day, a "second" edema develops, especially about the face; lungs may become edematous; bronchial catarrh, pneumonia, or pleurisy may appear; gradual recovery.

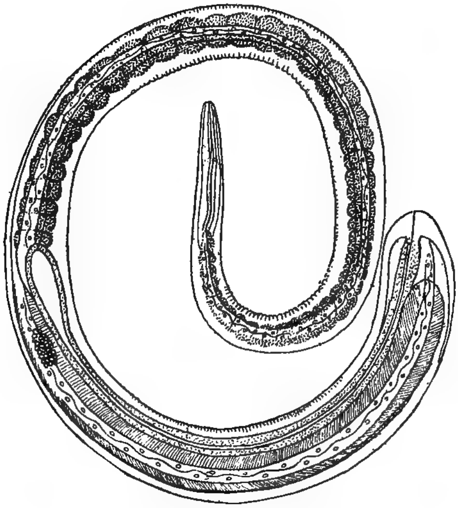


FIG. 46.—A female trichina from the muscle. Greatly enlarged. (After Leuckart, 1866a, pl. 1, fig. 12.)

Lethality.—The lethality varies from 0 to 100 per cent; it averaged 5.6 per cent in 14,820 cases collected from literature; it is dependent upon amount of infection which remains in the body; low before

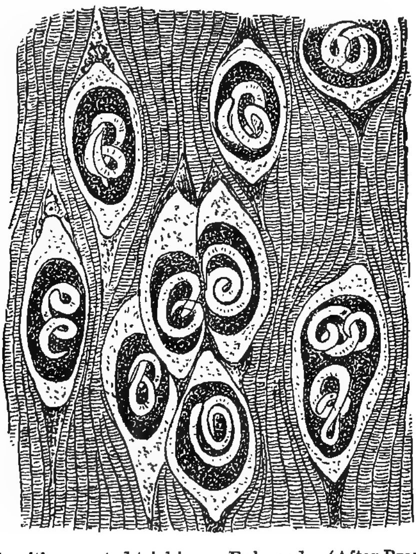


FIG. 47.—A piece of pork with encysted trichinæ. Enlarged. (After Braun, 1903, p. 251, fig. 195.)

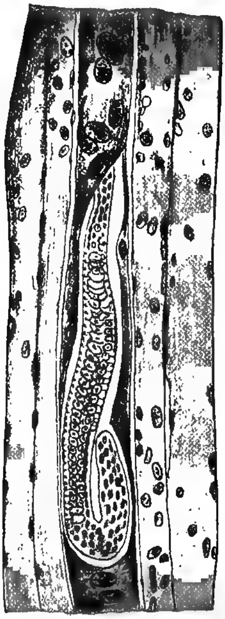
second and after seventh week, highest from fourth to sixth week.

Prognosis.—Better in cases having severe diarrhea in first stage.

Complications and sequelæ.—Abortion, menstrual disturbances, pneumonia, pleurisy, peritonitis.

Clinical diagnosis.—Make microscopic examination:

(1) Of pork, if any has been left, to find encysted larvæ; if larvæ are found, feed pork immediately to two or three guinea pigs or *white* rats, to determine if the encysted larvæ are alive; kill one rat after three days and examine intestinal content for adult; kill the second rat after two weeks, the third rat after three weeks, and hunt for larvæ in muscular portion of diaphragm. Even if live trichinæ are found



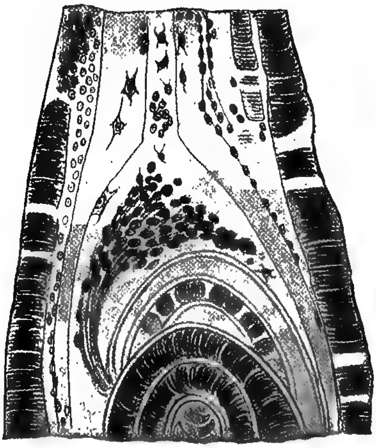


Fig. 48.—Section through a rat's muscle; the infected muscle fiber has lost its striation, its nuclei are enlarged and increased in number. Greatly enlarged. (After Hertwig-Grahan, see Braun, 1903, p. 284, fig. 212B.)

Fig. 49.—Portion of an isolated trichina cyst, at the pole of which connective tissue cells have wandered into the thickened sarcolemma. Greatly enlarged. (After Hertwig-Graham, see Braun, 1903, p. 284, fig. 212C.)

in intestine, an examination of the muscles may show that the worms were too weak to reproduce, hence prognosis is favorable.

(2) Of patient's blood, for increased proportion of eosinophiles.

(3) Of patient's stools, for discharged adult worms, especially if diarrhea is severe; dilute the fecal matter with warm water and pour off whatever floats; place remainder in a shallow glass dish so that it will not be over one-twelfth of an inch deep; move the dish gently around over a dark background (such as dark paper), and hunt for small hair-like objects; place these, if found, in a drop of water on a

slide, cover with a cover slip, and examine under low power. Or, if necessary, make a microscopic examination.

(4) Of small excised portion of patient's deltoid, about three to four weeks after infection, for encysted larvæ; cut a small piece parallel to muscle fibers, tease this on a slide, add a drop of pure

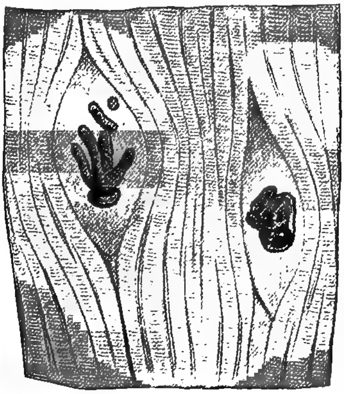


FIG. 50.—Calcified trichinæ in uncalcified cysts, from pork. Enlarged. (After Ostertag, see Braun, 1903, p. 285, fig. 213.)

water, or water and glycerine, cover with another slide, flatten gently by pressure while examining under low power.

Suspect trichinosis especially under following circumstances: Several patients in same family or in same neighborhood, usually of North German descent, show typhoid-like symptoms shortly after a celebration (wedding, birthday party, etc.) at which pork was served.

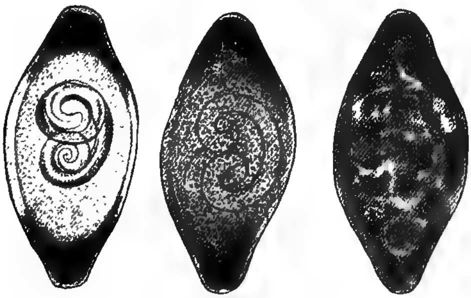


FIG. 51.—Three phases of calcification of trichinæ and their cysts, the changes starting from the poles of the cysts. Enlarged. (After Ostertag, see Braun, 1903, p. 285, fig. 214.)

Differential diagnosis.—Consider especially typhoid fever and rheumatism.

Treatment.—Purge in early stage to carry away the adult worms and thus eventually decrease the amount of muscular infection. No treatment is known which can be relied upon to kill the larvæ in the muscles; benzine has been suggested. Stimulants may be given to carry patients through until the larvæ encyst.

PROPHYLAXIS.—*Kill off rats and mice.*—Educate public to eat pork only when thoroughly cooked or thoroughly cured. A practical test of cooking is the white color of the meat on being cut; if the cut surface is reddish and serous, the pork is not sufficiently cooked to kill trichinæ.

As a matter of practical experience, the microscopic inspection of pork has not given the protection it is generally supposed to give. Of 6,329 cases with 318 deaths reported for Germany during the years 1881–1898, 3,388 cases with 132 deaths are directly attributable to faults in the inspection. This system directly increases the tendency to eat raw pork, gives the public a false sense of security, and does not give practical results commensurate with its expense.

ACANTHOCEPHALA—THORN-HEADED WORMS.

Genus GIGANTORHYNCHUS Hamann, 1892.

GENERIC DIAGNOSIS.—*Acanthocephala, Gigantorhynchidæ:* Large worms with annulate round to flat, tape-like body. Hooks with 2 roots and completely covered with transparent chitin. Proboscis sheath a muscular apparatus, without cavity. Central nervous system caudad of equator of proboscis sheath and eccentric. Lemnisci long, cylindrical, with central canal.

TYPE SPECIES.—*Gigantorhynchus echinodiscus* (Diesing, 1851).

The Moniliform Thorn-headed Worm—GIGANTORHYNCHUS MONILIFORMIS (Bremser, 1819).

[Figs. 52 to 58.]

SPECIFIC DIAGNOSIS.—*Gigantorhynchus* (p. 108): Body attenuated anteriorly, with fine transverse striæ or rings, or even constrictions which give the appearance of a series of beads, except in the caudal fourth of body, which is nearly smooth and cylindrical. Proboscis 425 to 450μ long, 176 to 190μ in diameter, armed with feeble, very curved, 26μ long, hooks arranged more or less in quincunx and forming at most 15 transverse and about 12 longitudinal rows. Lemnisci more than a centimeter in length, cylindrical, undulated posteriorly.

Male: Length 4 to 4.5 centimeters long; bursa campaniform.

Female: Length 7 to 8 centimeters (to 27 centimeters after Westrumb).

Eggs: Ellipsoidal, 85 by 45μ; external envelope thin, yellowish; middle envelope very thick, colorless, homogeneous; inner envelope less thick, colorless, and quite pliant. Embryo striated transversely in posterior two-thirds, and covered with spines which increase in size toward anterior end of embryo, the anterior spines being transformed into hooklets with prong and base.

Development: With beetles (*Blaps mucronata*) as intermediate host

HABITAT.—Small intestine of various small mammals; brown rat (*Mus decumanus*); white rat (*Mus norvegicus albus*); *M. fuscirostris;* hamster (*Cricetus frumentarius*); dormice (*Myoxus quercinus* or *glis*); field mole (*Arvicola arvalis* or *agrestris?*); *Lemnus arvalis;* and *Mustela putorius.* It can also develop in man, as has been shown experimentally by Grassi and Calandruccio (1888, 521–525).

MEDICAL SIGNIFICANCE.—Grassi and Calandruccio report a doubtful case of infection in a girl near Catania. Calandruccio infected himself experimentally by swallowing the young worms taken from a Blaps. Twenty days later he was seized with severe pains which increased on pressure; diarrhea followed, with ringing in the ears, fatigue, and somnolence. Seventeen days later the characteristic eggs were found in his stools, and twelve days later the symptoms became so severe that he took 8 grams of extract of male fern; one to two hours later he passed 53 of the parasites. For two days the

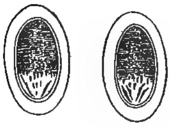


Fig. 56.

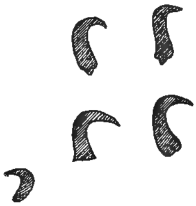


Fig. 55.

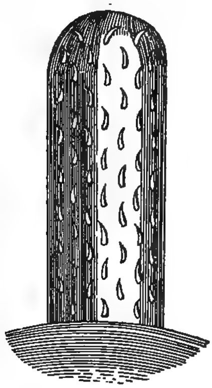
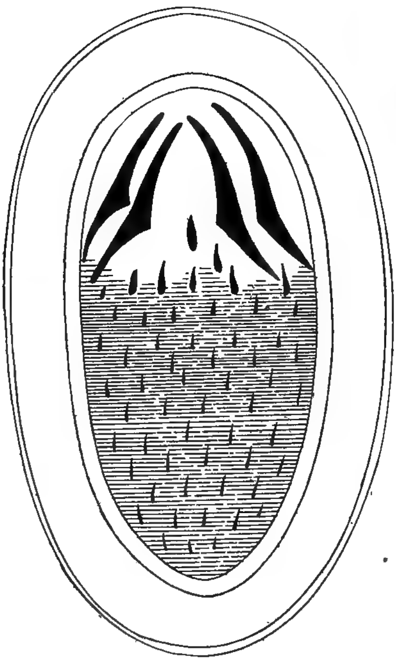


Fig. 54.



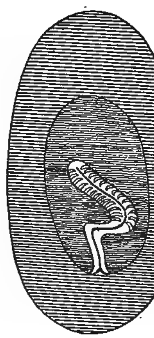


Fig. 52. Fig. 53. Fig. 57. Fig. 58.

Fig. 52.—*Gigantorhynchus moniliformis*, female. ×2. (After Grassi & Calandruccio, 1888, p. 523, fig. 1.)

Fig. 53.—*G. moniliformis*, male. ×2. (After Grassi & Calandruccio, 1888, p. 523, fig. 2.)

Fig. 54.—Rostellum of *G. moniliformis*. Greatly enlarged. (After Grassi & Calandruccio, 1888, p. 523, fig. 3.)

Fig. 55.—Hooks from same. Greatly enlarged. (After Grassi & Calandruccio, 1888, p. 523, fig. 4.)

Fig. 56.—Eggs of *G. moniliformis*, with embryo. Greatly enlarged. (After Grassi & Calandruccio, 1888, p. 523, fig. 5.)

Fig. 57.—Egg very greatly enlarged. (After Grassi & Calandruccio, 1888, p. 524, fig. 6.)

Fig. 58.—A young larva of *G. moniliformis* in a *Blaps;* the rostellum is invaginated and the larva is urrounded by a thick inner jelly-like and thin outer cuticular covering. Enlarged. (After Grassi & Calandruccio, 1888, p. 524, fig. 7.)

symptoms continued, on the second day fever developed, but all symptoms disappeared on the third day.

ARACHNOIDEA.

Genus LINGUATULA Frœhlich, 1789.—Tongue worms.

Species LINGUATULA SERRATA Frœhlich, 1789.

The larva of this parasite is found encysted in the entrails of rabbits, cattle, and certain other animals, and it becomes mature in the nasal cavities of canines.

Both the larva and the adult have been reported for man, and the larva has been reported as occurring in *Mus decumanus*.

As canines are not fond of eating rats, the presence of the larval tongue worm in the latter is of more academic interest than practical importance, and although the theoretical possibility must be admitted that a dog by eating rats might become infected with tongue worms and eventually might transmit the infection to man, these possibilities seem somewhat remote. Remote possibilities must also be admitted to the effect that if a person ate a rat infected with tongue worms this person might become infected.

COMPENDIUM OF ANIMAL PARASITES REPORTED FOR RATS AND MICE (GENUS MUS).

By Ch. Wardell Stiles, Ph. D., *Public Health and Marine-Hospital Service,*
and
Albert Hassall, M. R. C. V. S., *Assistant, Division of Zoology, United States Bureau of Animal Industry.*

The following list of parasites is prepared from the detailed host catalogues of the zoological divisions of the Public Health and Marine-Hospital Service and the Bureau of Animal Industry.

The species of hosts and parasites are taken as given by the various authors. It is needless to say that no list of this kind can ever lay claim to being complete.

Genus MUS Linneaus, 1758.

[*Mus musculus* should be the type species.]

MUS AGRARIUS.—Harvest Mouse.

Cestoda:
murina Dujardin: Hymenolepis.—Small intestine. [See fraterna.]

Nematoda:
obvelata: Oxyuris.—Intestine.

Arachnoidea:
acuminatus Neumann: Ixodes.—External.

Insecta:
fasciatus Bosc: Ceratophyllus.—External.
musculi Dugès: Ctenopsyllus, Ctenopsylla.—External.

MUS ALBIPES.

Insecta:
pallidus Taschenberg: Pulex.—External.

MUS ALEXANDRINUS.—Roof Rat.

[See also *Mus rattus alexandrinus*.]

Cestoda:
diminuta Rudolphi, 1819: Tænia, Hymenolepis.—Small intestine.
fasciolaris Rudolphi: Cysticercus.—Liver.
leptocephala: Tænia.—Small intestine.
murina Dujardin: Hymenolepis.—Small intestine. [See fraterna.]

MUS ALEXANDRINUS ALBIVENTRIS.

CESTODA:

diminuta Rudolphi: Hymenolepis.—Small intestine.

MUS AMPHIBIUS.

———

Dubium Rudolphi.—Inguinal gland.

CESTODA:

fasciolaris Rudolphi: Cysticercus.—Liver.
omphalodes Hermann: Tænia, Anoplocephala.—Intestine.

NEMATODA:

nodosus: Trichocephalus.—Cecum.
obvelata: Ascaris.

MUS ARVALIS.

CESTODA:

fasciolaris Rudolphi: Cysticercus.—Liver.
longicollis: Cysticercus.
omphalodes Hermann: Tænia, Anoplocephala.—Intestine.

NEMATODA:

nodosus: Trichocephalus.
obvelata: Ascaris.

ACANTHOCEPHALA:

moniliformis: Echinorhynchus.

MUS BARBARUS.

[See also *barbatus* Enderl.]

INSECTA:

spiculifer Gerv.: Hæmatopinus, Polyplax.—External.

MUS BRASILIENSIS Geoffr.

[See also *Holochilus brasiliensis.*]

CESTODA:

pisiformis Zeder: Cysticercus.

NEMATODA:

muris brasiliensis Diesing: Physaloptera.
obvelata Bremser: Oxyuris.

MUS CAPENSIS.

CESTODA:

muris capensis: Tænia.—Intestine.

NEMATODA:

contortus Rudolphi: Trichocephalus.—Cecum.

MUS CRICETUS.

CESTODA:

straminea Gœze: Tænia.—Intestine.

MUS DECUMANUS Pallas.—Brown or Norway Rat; German Wanderratte.

PROTOZOA:

? balfouri: Hæmogregarina.—Blood.
intestinalis Lambl, 1859: Lamblia.—Intestine. [See duodenalis.]
lewisi Saville-Kent: Herpetomonas, Trichomonas, Trypanosoma.—Blood.
species Siebold: Sarcocystis.—Muscles.

TREMATODA:

armata: Cercaria.
muris: Distomum.
spiculator Dujardin, 1845: Distoma, Echinostoma, Distomum, Echinostomum.—Small intestine.

CESTODA:

brachydera Diesing: Tænia.—Small intestine.
contracta Janicki: Hymenolepis.—Intestine.
crassa Janicki: Hymenolepis.—Intestine.
diminuta Rudolphi: Tænia, Hymenolepis.—Small intestine.
fasciolaris Rudolphi: Cysticercus.—Liver.
horrida Linstow, 1901: Tænia, Hymenolepis.—Intestine.
microstoma Dujardin: Tænia, Hymenolepis.—Small intestine.
murina Dujardin, 1845: Tænia, Hymenolepis.—Small intestine. [See fraterna.]
nana Siebold: Hymenolepis.—Small intestine. [See fraterna, murina.]
pusilla Gœze: Tænia, Catenotænia.—Small intestine.
ratti: Tænia.—Intestine.
relicta Zschokke, 1888: Tænia, Hymenolepis.—Small intestine.
species Janicki: Hymenolepis.
species: Hymenolepis.—Small intestine.

NEMATODA:

annulosum Dujardin: Trichosoma, Trichosomum, Calodium.—Duodenum, small intestine.
anulosum see annulosum Dujardin: Trichosoma.
circumflexa Polonio: Trichina.—Encysted in peritoneum.
crassicauda Bellingham, 1840: Trichodes, Trichosoma.—Urinary bladder, ureter, kidneys, intestine.
hepaticum Bauer: Trichosoma.—Liver.
hepaticum Railliet, 1891: Trichosoma.—Liver.
hepaticus Bancroft: Trichocephalus.—Liver.
longus Grassi & Segrè: Strongyloides, Rhabdonema.—Intestine.
minimum Molin: Gongylonema.
murina Leuckart: Spiroptera.—Stomach. [See obtusa.]
muris Gmelin: Filaria.—Stomach.
obtusa Rudolphi: Filaria, Spiroptera.—Stomach. [See murina.]
obvelata Bremser: Oxyuris.—Large intestine.
papillosum Polonio: Trichosoma.—Urinary bladder.
rhytipleuritis Deslongchamps: Filaria.—Stomach.
schmidtii Linstow: Trichosoma.—Urinary bladder.
species Davaine: Filaria [embryo].—Blood.
species: Heterakis.—Large intestine.
species undetermined: Oxyuris.
species Gerstæcker: Spiroptera.—Encapsuled in wall of stomach and intestine.
species Bakody: Spiroptera.—Encapsuled in walls of alimentary canal and muscles.
species: Spiroptera.—Encapsuled in wall of stomach and intestine.
species Parona: Strongyloides.
species Lutz, 1894: Strongylus.—Small intestine.
? species Railliet: Trichosoma.
spiralis Owen, 1835: Trichina, Trichinella.—Adult in intestine, larva in muscles.
spumosa Schneider: Heterakis.—Cœcum and large intestine.
? *tenuissimum* Leidy, 1891: Trichosomum.—Liver. [See hepaticum.]

ACANTHOCEPHALA:

moniliformis Bremser: Echinorhynchus, Gigantorhynchus.

ARACHNOIDEA:

agilis Koch: Lælaps.—External. [See echidninus, musculi.]
alepis Railliet & Lucet, 1893: Sarcoptes, Notoedres.—External, ears, genitalia.
complanatus Kramer: Gamasus.—External. [See stabularis, fenilis.]

Arachnoidea—Continued.

decumani Tiraboschi: Myonyssus.
echidninus Berlese: Lælaps.—External.
ensifera Poppe: Myobia.—External.
fenilis Mègnin: Gamasus.—[See stabularis, complanatus.]
musculi Schrank: Pediculus, Myobia.—External, head.
musculi Mègnin: Hæmomyson.—External. [See echidninus, agilis.]
musculi Schrank: Myobia.—External.
ricinus Linné: Acarus, Ixodes.—External. [See rufus, sulcatus, sciuri.]
rufus Koch: Ixodes.—External. [See ricinus.]
sciuri Koch: Ixodes.—External. [See ricinus.]
sp. n. Banks: Lælaps.—External.
stabularis Koch: Gamasus, Hypoaspis, Lælaps.—External. [See complanatus, fenilis.]
sulcatus Koch: Ixodes.—External. [See ricinus.]
tænioides Lamark (larva): Linguatula. [See serrata.]

Insecta:

acanthopus Denny: Hæmatopinus, Hoplopleura.—External.
bidentatiformis Wagner: Neopsylla.—External.
brasiliensis Baker: Pulex.—External.
canis Curtis: Ctenocephalus, Ceratophyllus.—External.
cheopis Roth.: Pulex, Læmopsylla.—External.
consimilis Wagner: Ceratophyllus.—External.
fasciatus Bosc: Pulex, Ceratophyllus. External.
felis Bouché: Ctenocephalus.—External.
irritans Linné: Pulex.—External.
lagomys Wagner: Ceratophyllus.—External.
londiniensis Roth.: Ceratophyllus.—External.
musculi Dugès: Ctenopsylla.—External.
mustelæ Wagner: Ceratophyllus.—External.
penicilliger Grube: Ceratophyllus.—External.
philippinensis Herzog: Pulex.—External.
serraticeps Gervais: Pulex.—External.
spinulosus Burmeister: Hæmatopinus, Polyplax.—External.

MUS DECUMANUS × MUS NORVEGICUS ALBUS.

Protozoa:

undetermined.—Small intestine.

Cestoda:

fasciolaris: Cysticercus.—Liver.
species: Hymenolepis.—Intestine.

Nematoda:

spiralis Owen: Trichinella.—Artificial infection.

MUS DOMESTICUS=MUS MUSCULUS ALBUS.

Arachnoidea:

crotali Humboldt (larva): Porocephalus.—Encysted in various organs, experimental.

MUS FERCULINUS.

Insecta:

thomasi Rothschild: Stephanocircus.—External.

MUS FLAVIDUS.

Cestoda:

? *gracilis* Janicki: Davainea.—Intestine.

MUS FULIGINOSUS.

ARACHNOIDEA:

crotali Humboldt: Porocephalus.—Encysted in various organs.

MUS FURCIROSTRIS Wagner.

ACANTHOCEPHALA:

moniliformis Bremser: Echinorhynchus.—Intestine.

MUS GENTILIS.

INSECTA:

cheopis Rothschild: Pulex.—External.

MUS LEMMUS.

CESTODA:

lemmi: Tænia.—Intestine. [See muris lemmi.]
muris lemmi: Tænia.—Intestine. [See lemmi.]

MUS MEYERI.

CESTODA:

celebensis Janicki, 1902: Davainea.—Intestine.

MUS MINIMUS Ptrs.

NEMATODA:

species Linstow, 1901: Spiroptera.—Stomach.

MUS MINUTUS Pallas.—German Zwergmaus.

NEMATODA:

obvelata Bremser: Oxyuris.—Cecum.
oxyura Nitzsch, 1821: Ascaris.—[See obvelata.]

MUS MUSCHENBROCKI.

CESTODA:

polycalceola Janicki: Davainea.—Intestine.

MUS MUSCULUS [a] Linné, 1758.—House Mouse.

———:

Dubium Rudolphi, 1819.—Inguinal gland.

PROTOZOA:

brucei: Trypanosoma, Trypanozoon.—Blood, artificial infection.
dimorphon: Trypanosoma, Trypanozoon.—Blood.
duttoni Thiroux, 1905: Trypanosoma, Trypanozoon.—Blood.
equinum: Trypanosoma, Trypanozoon.—Blood, artificial infection.
equiperdum: Trypanosoma, Trypanozoon.—Blood, artificial infection.
evansi: Trypansoma, Trypanozoon.—Blood, artificial infection.
falciforme Schneider: Coccidium, Eimeria.—Intestine.
flagellate, something like Herpetomonas bütschlii.
gambiense: Trypanosoma, Trypanozoon.—Blood, artificial infection.
intestinalis Lambl, 1859: Lamblia, Megastoma.—Intestine. [See duodenalis, muris.]
muris Grassi: Amoeba.
muris Bensen, 1908: Lamblia.—Intestine. [See intestinalis.]
muris Schuberg: Coccidium.—Intestine.
muris Smith & Johnson, 1902a: Klossiella.—Renal epithelium.

---

[a] In laboratory experiments the white mouse is used more than the ordinary form, but the host is frequently reported simply as "the mouse."

PROTOZOA—Continued.

muris Balfour: Leucocytozoon.—Blood.
muris R. Blanchard: Miescheria, Sarcocystis.—Striated muscle.
musculi Kendall: Trypanosoma.—Blood.
schubergi Labbé: Pfeifferella.—Intestine.
species Th. Smith: Eimeria.—Kidney.
species J. J. Clarke: Pfeifferella.—Intestine.
species Miescher: Sarcocystis.—Muscles.
stercorea Cienkowsky: Chlamydophrys.—Intestine.

TREMATODA:

armata: Cercaria.
muris Ercolani, 1882: Distomum.
musculi Rudolphi, 1819: Distoma, Distomum.—Intestine.
recurvum Dujardin, 1845: Distoma, Distomum.—Intestine.

CESTODA:

canis lagopodis Viborg: Tænia.—Intestine. [See lineata.]
contracta Janicki: Hymenolepis.—Intestine.
crassa Janicki, 1904: Hymenolepis.—Intestine.
diminuta Rudolphi: Tænia, Hymenolepis.—Intestine.
echinococcus. [See Devé, 1904, October 28, 264.]
fasciolaris Rudolphi, 1819: Cysticercus.—Liver.
imbricata Diesing: Tænia.—Small intestine.
leptocephala Creplin, 1849: Tænia.—Small intestine.
lineata Gœze: Tænia, Mesocestoides, Ptychophysa. [See canis lagopodis.]
microstoma Dujardin, 1845: Tænia.—Intestine.
murina Dujardin, 1845: Tænia, Hymenolepis.—Intestine. [See fraterna.]
muris capensis: Tænia.
muris hepatica Rœderer, 1762: Fasciola.—Liver. [See fasciolaris.]
musculi Rudolphi, 1810: Tænia.—Abdominal cavity.
pisiformis Zeder: Cysticercus.—Liver.
pusilla Gœze, 1782: Tænia.—Intestine.
species Janicki: Hymenolepis.—Intestine.
species Merrem, 1781: Fasciola.—Liver. [See fasciolaris.]
tenella Pallas, 1781 pars: Tænia.—Abdominal cavity. [See musculi.]
umbonata Molin, 1858: Tænia.—Intestine.

NEMATODA:

bacillatum Eberth: Trichosoma.—Esophagus.
hepaticum Railliet, 1889: Trichosoma.—Liver.
minimum Molin: Gongylonema.—On stomach, liver.
muris Gmelin: Filaria.
muris Werner: Lumbricus, Ascaris, Fusaria. [See obtusa Frœlich.]
muris musculi Creplin, 1849: Trichosoma.—Large intestine.
musculi Rudolphi: Filaria, Gongylonema.—Abdomen.
nodosus Rudolphi: Trichocephalus.—Intestine, cecum
oxyura Nitzsch, 1821: Ascaris.—[See obvelata.]
obvelata Rudolphi: Oxyuris.—Cecum.
obtusa Rudolphi: Filaria, Spiroptera.—Stomach.
obtusa Frœlich, 1791: Ascaris.—Stomach. [See muris Werner.]
quadrialata Molin: Spiroptera.—Stomach.
semilanceolata Molin, 1858: Oxyuris.—Cecum. [See tetraptera.]
spiralis Owen, 1835: Trichina, Trichinella.—Adult in intestine, larva in muscles.
tetraptera Nitzsch: Oxyuris.—Cecum. [See semilanceolata.]
tricuspis Leuckart: Ollulanus.—Muscles.

ACANTHOCEPHALA:

muris Zeder: Echinorhynchus.—Stomach.

ARACHNOIDEA:

coarctata Heyden: Myobia.—External. [See musculi Schrank.]
musculi Oudemans: Demodex.—Hair follicles. [See folliculorum musculi.]
musculi Schrank: Pediculus, Myobia.—External, head.
musculinus Galli-Valerio: Myocoptes.—External.
simplex Tyrrell: Psorergates.—External.

INSECTA:

acanthopus Burmeister, 1838: Hoplopleura, Hæmatopinus.—External.
agyrtes Heller: Typhlopsylla.—External.
assimilis Taschenberg: Typhlopsylla.—External.
charlottensis Baker: Odontopsyllus.—External.
fasciatus Bosc: Ceratophyllus.—External.
italicus Tiraboschi: Ceratophyllus.—External.
londiniensis Roth.: Ceratophyllus.—External.
musculi Dugès: Ctenopsyllus, Ctenopsylla, Typhlopsylla.—External.
serratus Burm., 1838: Hæmatopinus.—External.
serraticeps Taschenberg: Ctenocephalus.—External.
larva of a dipteron, gen. sp.?
taschenbergi Wagner: Ctenopsyllus.—External.
tripectinata Tiraboschi: Hystrichopsylla.—External.
walkeri Roth.: Ceratophyllus.—External

MUS MUSCULUS ALBUS.—White Mice.

CESTODA:

fasciolaris Rudolphi: Cysticercus.—Liver.

ARACHNOIDEA:

crotali Humboldt (larva): Porocephalus.—Encysted in various organs.
proboscideum: Pentastomum. [See crotali.]

MUS NAVALIS.

NEMATODA:

labiodentata Linstow: Spiroptera.—Intestine.

MUS NORVEGICUS Erxl.—Norway Rat.

[See also *Mus decumanus.*]

PROTOZOA:

lewisi: Trypanosoma, Trypanozoon.—Blood.

INSECTA:

bidentatiformis Wagner: Ctenophthalmus.—External.
brasiliensis Baker: Pulex.—External.
fasciatus Bosc: Ceratophyllus.—External.
italicus Tiraboschi: Ceratophyllus.—External.
murinus Tiraboschi: Pulex.—External.
musculi Dugès: Ctenopsyllus.—External.

MUS [NORVEGICUS] ALBUS.—White Rat.

PROTOZOA:

muris Fantham: Piroplasma.—Blood.
perniciosum Miller: Hepatozoon.—Liver, blood.

CESTODA:

fasciolaris Rudolphi: Cysticercus.—Liver.

NEMATODA:

hepaticum: Trichosoma.—Liver.
spiralis Owen, 1835: Trichinella.—Adult in intestine, larva in muscle.

ARACHNOIDEA:

ensifera Poppe: Myobia.

MUS PUMILIS Dujardin.—Little Mouse.

CESTODA:

murina Dujardin, 1845: Tænia, Hymenolepis.—Intestine. [See fraterna.]

MUS PYRRHORHINUS Neuwied.

[See also *Hesperomys pyrrhorhinus*.]

CESTODA:

diminuta: Tænia.—Intestine.

ARACHNOIDEA:

crotali Humboldt: Porocephalus.—Encysted in various organs.
subcylindricum: Pentastomum.—Liver.

MUS RAJAH.

CESTODA:

blanchardi Parona: Davainea.

MUS RATTUS Linné.—German Hausratte.

PROTOZOA:

"amibes."
intestinalis Lambl, 1859: Lamblia.—Intestine. [See duodenalis, muris.]
lewisi Saville-Kent, 1880: Trypanosoma.—Blood.
species Siebold: Sarcocystis.—Muscles.

TREMATODA:

spiculator: Distomum.

CESTODA:

cellulosæ Rudolphi: Cysticercus.—Peritoneum.
diminuta Rudolphi, 1819: Tænia, Hymenolepis.—Small intestine.
fasciolaris Rudolphi: Cysticercus.—Liver.
microstoma Dujardin: Tænia, Hymenolepis.—Small intestine.
minima: Tænia. [See diminuta.]
murina Dujardin, 1845: Tænia, Hymenolepis.—Small intestine. [See fraterna.]
pusilla Gœze, 1782: Tænia, Catenotænia.—Small intestine.
ratti Rudolphi: Tænia.—Small intestine.
ratticola Linstow: Bothriocephalus.—Liver.
species Eber: Tænia.—Intestine.
umbonata Molin: Tænia.—Intestine.
varesina Parona: Tænia.—[See diminuta.]

NEMATODA:

annulosum Dujardin: Trichosoma, Calodium.—Intestine.
anulosum: Trichosoma. [See annulosum.]
brauni Linstow: Spiroptera.
circularis Linstow: Physaloptera.—Stomach.
circumflexa Polonio: Trichina.—Encysted in peritoneum.
nodosus Rudolphi: Trichocephalus.—Cecum.
obvelata Bremser: Oxyuris.—Cecum.
oxyura Nitzsch, 1821: Ascaris. [See obvelata.]
ratti Diesing: Spiroptera.—Urinary bladder.
rhytipleuritis Deslongchamps: Filaria.—Stomach.

NEMATODA—Continued.

species Gerstæcker: Spiroptera.—Wall of stomach and intestine.
species Bakody: Spiroptera.—Encapsuled in wall of intestine, muscles.
spumosa Schneider: Heterakis.—Cecum, colon.

ACANTHOCEPHALA:

moniliformis Bremser: Echinorhynchus, Gigantorhynchus.—Intestine.

ARACHNOIDEA:

ægyptium Linné: Acarus, Ixodes, Hyalomma.—External. [See marginatum.]
agilis Koch: Lælaps.—External. [See echidninus, musculi.]
alepis Railliet & Lucet, 1893; Sarcoptes, Notoedres.—External, ears, genitalia.
echidninus Berlese: Lælaps.—External. [See agilis, musculi.]
marginatum Koch: Hyalomma.—External. [See ægyptium.]
muris Can., 1894: Notoedres.—External. [See alepis.]
musculi Mègnin: Hæmomyson.—External. [See agilis, echidninus.]
serratum: Pentastomum.—Thoracic cavity.

INSECTA:

brasiliensis Baker: Pulex.—External. [See cheopis.]
cæcata Enderlein: Dermatophilus, Rhynchoprion.—External.
cheopis Rothschild, 1903: Lœmopsylla.—External. [See brasiliensis, murinus, pallidus, philippinensis.]
fasciatus: Ceratophyllus.—External.
gallinacea Westwood: Echidnophaga, Argopsylla.—External.
irritans Linné: Pulex.—External.
italicus Tiraboschi: Ceratophyllus. External.
londiniensis Rothschild: Ceratophyllus.—External.
mexicanus Baker: Ctenopsyllus.—External.
murinus Tirab.: Pulex.—External. [See cheopis, pallidus, brasiliensis, philippinensis.]
musculi Dugès: Ctenopysllus.—External.
pallidus Taschenberg: Pulex.—External. [See brasiliensis, cheopis, murinus, philippinensis.]
philippinensis Herzog: Pulex.—External. [See brasiliensis, cheopis, murinus, pallidus.]
rhynchopsylla Tiraboschi: Echidnophaga.—External.

MUS RATTUS ALEXANDRINUS.

[See also *Mus Alexandrinus.*]

INSECTA:

brasiliensis Baker: Pulex.—External.
cæcata End: Dermatophilus.—External.
canis Curtis: Ctenocephalus.—External.
cheopis Roth.: Pulex.—External.
fasciatus Bosc: Ceratophyllus.—External.
felis Bouché: Ctenocephalus.—External.
gallinacea Westwood: Echidnophaga.—External.
irritans Linné: Pulex.—External.
londiniensis Roth.: Ceratophyllus.—External.
murinus Tiraboschi: Pulex.—External.
musculi Dugès: Ctenopsylla.—External.
philippinensis Herzog: Pulex.—External.
rhynchopsylla Tiraboschi: Echidnophaga, Argopsylla.—External.

MUS RUFESCENS Gray.

PROTOZOA:

lewisi Saville-Kent, 1880: Trypanosoma, Trypanozoon.—Blood.

MUS SIPORANUS.

CESTODA:

blanchardi Parona: Davainea.—Intestine.

MUS SURIFER.

NEMATODA:

muricola: Spiroptera.—Subcutaneous.

MUS SYLVATICUS Linné.—German Waldmaus.

TREMATODA:

recurvum Dujardin, 1845: Distoma, Distomum, D. (Brachylaimus).—Intestine.
vitta Dujardin, 1845: Distoma, Distomum, D. (Brachylaimus).—Intestine.

CESTODA:

muris sylvatici Rudolphi: Tænia.—Intestine.
pusilla Gœze: Tænia.—Intestine.

NEMATODA:

cristatum Rudolphi: Ophiostomum, Rictularia.—Intestine.
lævis Dujardin: Strongylus, Metastrongylus.—Intestine.
minutus Dujardin: Strongylus, Metastrongylus.—Intestine.
muris sylvatici Dujardin: Trichosoma.—Intestine.
nodosus Rudolphi: Trichocephalus.—Intestine, cecum.
obtusa Rudolphi: Spiroptera.
obvelata Bremser: Oxyuris.—Cecum.
oxyura Nitzsch, 1821: Ascaris. [See obvelata.]
polygyrus Dujardin: Strongylus, Metastrongylus.—Intestine.
spirogyrus Leuckart: Strongylus.—Intestine.
stroma Linstow, 1884: Oxyuris.—Intestine.
tetraptera Nitzsch: Oxyuris.—Intestine.

ARACHNOIDEA:

simplex Tyrell: Psorergates.—Skin.

INSECTA:

agyrtes Heller: Ctenophthalmus, Typhlopsylla.—External.
assimilis Taschenberg: Typhlopsylla.—External.
fasciatus Bosc: Ceratophyllus.—External.
gallinæ Schrank: Ceratophyllus.—External.
italicus Tiraboschi: Ceratophyllus.—External.
londiniensis Rothschild: Ceratophyllus.—External.
musculi Dugès: Ctenopsyllus, Ctenopsylla.—External.
obtusiceps Ritsema: Hystrichopsylla.—External.
pentacanthus Rothschild: Neopsylla, Ctenophthalmus.—External.
poppei Wagner: Typhloceras, Typhlocerus.—External.
proxima Wagner: Typhlopsylla, Ctenopthalmus.—External.
talpæ Curtis: Hystrichopsylla.—External.
taschenbergi Wagner: Ctenopsylla.—External.

MUS SYLVESTRIS.

PROTOZOA:

intestinalis Lambl, 1859: Lamblia.—Intestine. [See muris.]

MUS TECTORUM Sari.

CESTODA:

fasciolaris: Cysticercus.—Liver.

MUS VARIEGATUS.

CESTODA:

muris variegati Janicki: Hymenolepis.—Intestine.
trapezoides Janicki: Davainea.—Intestine.

MUS VELUTINUS Balser, 1905.

INSECTA:

dasyuri Skuse: Stephanocircus.—External.
hercules Roth.: Macropsylla.—External.
simpsoni Rothschild: Stephanocircus.—External.
simsoni. [See simpsoni.]

MUS in the sense of "rats."

The following parasites are reported either from "rats" or from "*Mus*" in the sense of "rats:"

PROTOZOA:

brucei: Trypanosoma, Trypanozoon.—Blood.
dimorphon: Trypanosoma, Trypanozoon.—Blood.
equiperdum: Trypanosoma, Trypanozoon.—Blood.
evansi: Trypanosoma, Trypanozoon.—Blood.
evansii: Trypanosoma. [See evansi.]
gambiense: Trypanosoma, Trypanozoon.—Blood, artificial infection.
intestinale R. Blanchard, 1885: Megastoma.—Intestine. [See muris.]
muris Grassi: Amœba.

CESTODA:

fasciolaris: Cysticercus.

NEMATODA:

hepaticum Railliet, 1889: Trichosoma.—Liver.
hepaticus: Trichocephalus.
species Davaine: Filaria.—Blood.

GORDIACEA:

Gordius. By error Cerruti & Camerano (1888b, 6) have interpreted a title by Leidy (1879) as meaning that he found *Gordius* in a rat.

ARACHNOIDEA:

sanguineus Latreille: Rhipicephalus.—External.

INSECTA:

capitis Nitzsch: Pediculus.—External.
canis Curtis: Ctenocephalus.—External.
præcisus: Hæmatopinus.—External.

MUS species.

Under various "*Mus* sp." entries, the following parasites are reported:

PROTOZOA:

gambiense: Trypanosoma.—Blood, artificial injection.

INSECTA:

aganippes Roth.: Ctenopsylla.—External.
agyrtes Heller: Typhlopsylla.—External.
colossus Roth.: Pygiopsylla.—External.
ellobius Roth.: Ctenopsylla.—External.
hercules Roth.: Macropsylla.—External.
miacantha: Polyplax.—Hair.
pinnatus Wagn.: Ceratophyllus.—External.
præcisus Neum., 1902: Hæmatopinus.—External.

WATER RAT.

[See also *Mus amphibius*.]

CESTODA:

longicollis: Cysticercus.—Axillary space.

INSECTA:

spiniger Burm., 1838: Hæmatopinus.

MUS.

The following parasites are recorded under "*Mus:*"

PROTOZOA:

falciformis: Eimeria.—Intestine.

TREMATODA:

migrans: Dist.

CESTODA:

blanchardi Parona: Davainea.
celebensis Janicki: Davainea.
gracilis Janicki: Davainea.
muris variegati Janicki: Hymenolepis.
nana Siebold: Hymenolepis. [See fraterna.]
polycalceola Janicki: Davainea.
relicta Zschokke: Hymenolepis.
trapezoides Janicki: Davainea.

NEMATODA:

hepaticum Railliet: Trichosoma.
obvelata Bremser: Oxyuris.—Intestine.

ARACHNOIDEA:

musculi Oudemans: Demodex.

INSECTA:

cheopis Roth.: Lœmopsylla.—External.
felis Bouché: Ctenocephalus.

MUS.—A Field Mouse.

CESTODA:

longicollis: Cysticercus.—Thoracic cavity.

THE FLEA AND ITS RELATION TO PLAGUE.

By Passed Assistant Surgeon CARROLL FOX,
United States Public Health and Marine-Hospital Service.

THEORIES AS TO TRANSMISSION OF PLAGUE.

1. Direct contagion from man to man.
2. Through slight abrasions of the skin, mucous membranes of mouth, tonsils, nose, and conjunctiva receiving contaminated material.
3. Through the respiratory tract, from air contaminated with dried infectious sputum or dejecta. (Possibly the cause of primary pneumonic plague.)
4. Through the alimentary tract from food contaminated with saliva or excretions from plague patients, or dejecta or the feet of insects that have fed on plague material. In the case of rats, from eating the carcasses of infected rats.
5. Infected clothes, soil, or houses.
6. Through the bites of insects, especially the flea.

It has been noticed for many years that an epidemic of plague in man was associated with an epizootic of high mortality among rats, but it was not until Yersin discovered the *Bacillus pestis* in 1894 that the disease in man and rats was shown to be identical. The first five theories are not satisfactory in explaining the epidemiology of plague, and in 1897 Simond advanced the theory that plague was carried by means of fleas. Hankin in 1898 also suggested an insect as an intermediate host. This theory has been developed by Ashburton Thompson, Gauthier and Raybaud, Liston, Verjbitski, and others, and finally by the last Indian Plague Commission, whose work makes a distinct advance in our knowledge of this subject. The reader is referred to the work of this commission for a review of the subject, which has been liberally used in the preparation of this paper.[a]

[a] Journal of Hygiene (Vol. VI, No. 4; Vol. VII, No. 3; Vol. VII, No. 6; Vol. VIII, No. 2).

INSECTS THAT HAVE BEEN SUSPECTED IN THE TRANSMISSION OF PLAGUE.

It is probable that all insects capable of sucking blood will take the *Bacillus pestis* into their alimentary canal if they feed on a septicæmic plague animal. Ogata suggested that not only the flea but the mosquito also may be responsible for the transmission of plague. Yersin, Hankin, and Nuttall have each demonstrated the presence of *Bacillus pestis* in the dejecta of flies and ants; and Nuttall and Verjbitski in the stomach and dejecta of the bedbug. Hertzog found the bacilli in the *Pediculus capitis* taken from a child which died of plague, and McCoy (1) has found the organism in lice, *Haematopinus columbianus*, taken from a plague-infected squirrel. The plague bacilli have been frequently demonstrated in rat fleas taken from plague rats, and McCoy has shown its presence in the flea (*Ceratophyllus acutus*) of the California ground squirrel (*Citellus beecheyi*). The cockroach has also been thought to be instrumental in spreading the infection by contaminating food. The presence of bacilli in the stomach and dejecta of insects has not only been proven microscopically but by animal inoculation as well.

Assuming that the relation between rat plague and human plague has been proven without a doubt—that is, that an outbreak of human plague is associated with an infection in rats, or, in other words, that plague is primarily a disease of rats and secondarily a disease of man—the theory that it is conveyed through an intermediate parasitic host is the only one which will fulfill all the requirements, and after a study of their habits we are able to exclude all of the parasites but the flea as the active agent in its transmission.

Plague is rarely or never contracted either in rat or in man by eating contaminated food. Therefore those insects like flies and cockroaches, which are supposed to spread the infection by contaminating food with their dejecta, need not be considered.

The habits of the domestic mosquitoes are such that while they occasionally do bite animals they usually feed on the blood of man, and are not known to feed where there is much hair, as there is on the rat. This also applies to the bedbug. Verjbitski has shown experimentally that bedbugs would not feed on rats until the animals were shaved.

Pediculi are degenerate insects, their powers of locomotion being limited. Their eggs are laid on and are attached to the hair of the host. They are born, live, and die on the same host, and rarely pass from one animal to another of a different species. It can not be denied, however, that this parasite occasionally may be instrumental in spreading plague from rat to rat. The *Pediculus capitis*, if placed on a rat, will feed with avidity, but these insects are rarely found upon rats in nature.

We have no record of plague bacilli having been demonstrated in mites commonly found on rats, but no doubt if search be made they could be found after feeding on a septicæmic plague rat. These mites, however, always confine themselves closely to their particular host and are not known to bite man. The tiny itch mite (*Notoedres alepis*, Railliet and Lucet) producing rat scabies has, according to Schumann, (2) been known to cause a cutaneous lesion in man, but this mite need not be considered from a plague standpoint.

The flea, on the other hand, lives but part of the time on its host, its eggs developing in the nests or runs of the animal. Again, this insect does not confine itself to one particular species of host only, as frequently the flea of one animal is found on an animal of an entirely different species. Unlike the lice, they are very active and can readily move from place to place. Not only that, but it has been frequently demonstrated that the fleas of rats and of other animals would readily take to man, especially if their natural host was scarce. That rat fleas will bite man has been demonstrated by Gauthier and Raybaud, working with the *Leomopsylla cheopis;* Tidswell, *Loemopsylla cheopis* and *Ceratophyllus fasciatus;* Liston, *Loemopsylla cheopis;* Tiraboschi, *Loemopsylla cheopis*; Indian Plague Commission, *Loemopsylla cheopis;* and McCoy and Mitzmain (3), *Loemopsylla cheopis*, *Ceratophyllus fasciatus*, and *Ctenopsyllus musculi*. It has generally been considered that the *Ctenopsyllus musculi*, above all others, would not bite man, but the last-named observers showed that it would occasionally feed, although it would not live long, in captivity. One of the fleas, a *Ceratophyllus fasciatus*, was kept alive by Mitzmain for over four months on man's blood alone.

EXPERIMENTS PROVING THAT FLEAS CAN TRANSMIT PLAGUE.

By a series of experiments carried out in specially constructed cages and godowns where healthy rats in the absence of fleas were brought in contact with plague-infected rats, the Indian Plague Commission showed that the healthy rats would not contract the disease, notwithstanding the fact that they were not only in intimate contact with the sick rats, but also with the contaminated food and excreta of the sick rats. They then showed that if fleas were introduced the healthy rats would contract plague, the rate of progress of the epizootic being in direct proportion to the number of fleas present. By hanging cages containing healthy rats in cages holding infected rats, but above the jumping distance of a flea, it was shown that the healthy rats would remain well, while those in cages hung within 2 inches from the ground would contract plague. Thus they excluded aerial infection. They also found that if fleas were excluded young rats could suckle a plague-infected mother without contracting the disease.

Guinea pigs were allowed to run in houses where cases of human and of rat plague were known to have occurred and where many fleas were present. These rodents served as good traps for the fleas and 29 per cent of them contracted plague.

Most of the experiments of the Indian Plague Commission were done with the Indian rat flea, the *Læmopsylla cheopis*, but they also performed 27 experiments with the cat flea, *Ctenocephalus felis*, with negative results; 35 experiments with the human flea, *Pulex irritans*, 3 of which were successful; and 2 experiments with the *Ceratophyllus fasciatus*, the common rat flea of Europe and North America, both of which were successful.

In San Francisco a few experiments under purely experimental conditions have been carried on by McCoy to determine the ability of the squirrel flea, the *Ceratophyllus acutus*, to transmit plague. Fleas that had been previously fed on the blood of a septicæmic plague-infected squirrel were then allowed to feed from test tubes on healthy guinea pigs. While the feces of some of these fleas up to four days, when inoculated into guinea pigs, were proven to be infective, none of those guinea pigs on which the fleas were allowed to feed contracted plague. It might be said, however, that in no case were they seen to eject feces while feeding, the significance of which will be apparent later.

THE BACILLUS IN THE FLEA.

The Indian Plague Commission found that the average capacity of the rat flea's stomach (*Leomopsylla cheopis*) was 0.5 cubic millimeter, and that it might receive as many as 5,000 germs while imbibing blood from a plague rat. They further found that the bacillus would multiply in the stomach of a flea and that the percentage of fleas with bacilli in the stomach varied with the season of the year. In the epidemic season the percentage was greatest for the first four days, and on one occasion the stomach was found filled with *Bacillus pestis* on the twentieth day. In the nonepidemic season no plague bacilli were found in the stomach after the seventh day. They also found that in the epidemic season fleas might remain infective up to fifteen days, while in the nonepidemic season but seven days, and in the latter case the percentage of infection in animals was much less than in the epidemic season. They showed that while one flea was occasionally able to carry the infection this was not usual. It was found that both the males and the females were capable of transmitting the disease.

After a number of dissections they were unable to demonstrate the presence of bacilli anywhere but in the stomach and rectum. At no time was anything found in the body cavity or salivary glands and but rarely in the oesophagus, and then only when the flea was killed immediately after feeding.

We have in San Francisco examined quite a number of serial sections of plague-infected fleas with the same result as obtained by the Indian Plague Commission. The bacilli are readily demonstrated, sometimes in enormous numbers, in the gizzard, stomach, and in the rectum, but at no time have they been found in the body cavity, the salivary glands, or the ovary. In fact, as we are dealing with a vegetable organism and not an animal organism, like the *Plasmodium malariæ*, we could hardly expect to find any biologic change, except simple multiplication, occurring in the intermediate host.

HOW THE FLEA CLEARS ITSELF OF BACILLI.

Some explanation is necessary as to why the bacilli eventually disappear from the flea, although they seem to multiply during the first few days. It is evident that the peristaltic action of the stomach during the course of digestion forcing the blood at the proper time into the rectum, finally to be ejected from the body, would in itself cause many bacilli to be discharged, but naturally a few would remain to multiply indefinitely. The bacteriacidal action of the blood is soon lost after entering the flea's stomach, but it has been shown by proper staining that the leucocytes after the first feeding with healthy blood contain numbers of *Bacillus pestis*, and it seems probable that this phagocytic action is important in the cleansing process. It has been shown that after successive feedings on the blood of noninfected animals the power of phagocytosis is increased, and that successive feedings on the fresh blood of animals that have been immunized against plague still further assists and hastens the process. When there is a frequent introduction of fresh normal or immunized blood its bactericidal action is also instrumental in the cleansing process.

REGIONAL DISTRIBUTION OF FLEAS ON RATS.

The location of the primary bubo in a case of plague, human or rodent, depends upon the site of inoculation, for that group of glands will first enlarge which has direct lymphatic connection with the area through which the *Bacillus pestis* enters the animal organism. The British Indian Plague Commission found that 72 per cent of their naturally infected rats and 61 per cent of the rats experimentally infected by fleas had cervical buboes, while in no instance in over 5,000 plague rats was a mesenteric bubo encountered. On the other hand, where plague was induced through feeding healthy rats with the carcasses of plague rats a mesenteric bubo was found in 74.5 per cent of those infected and a cervical bubo in 36 per cent. In San Francisco in naturally infected rats a primary mesenteric bubo has never been seen, and a cervical bubo has been seen but once. These figures show conclusively that naturally infected rats are not infected by feeding. It is curious, as has been pointed out by McCoy (4), that such a large percentage of cervical buboes should be found in India, while a cervical bubo has been seen but once in naturally infected animals in San Francisco. Here the axillary and inguinal buboes are the rule. The Indian Commission found that the commonest situation to find fleas on guinea pigs was the head and neck. They combed 53 guinea pigs to determine the regional distribution of fleas, and found that 65.3 per cent were taken from the neck and head. This would account for the preponderance of cervical buboes in guinea pigs observed in their work, and inferentially for the preponderance of cervical buboes found in naturally infected rats. Thinking that the predominating rat flea in San Francisco, the *Ceratophyllus fasciatus,* might be the carrier of the infection and that it might prefer a different part of the body than the *Læmopsylla cheopis,* McCoy and Mitzmain carried on a series of investigations to determine the regional distribution of fleas on the rat's body, but this has shown that while the *Ctenopsyllus musculi* seems to be generally confined to the head and neck, the *Ceratophyllus fasciatus* and *Læmopsylla cheopis* are almost invariably taken from the body, especially from the pelvic region.

ANATOMY OF THE MOUTH PARTS OF THE CERATOPHYLLUS FASCIATUS.

The following description differs somewhat from that given by Wagner (5) and the description found in the Journal of Hygiene, both of which, however, refer to different species of Siphonaptera.

The mouth parts may be divided into those inside and those outside of the head.

OUTSIDE THE HEAD.

The epipharynx, or pricker, is a long, slender, hollow organ. Its cavity is closed distally, and proximally connects with the hoemocoel. It is made up of a dorsal and a ventral portion. Its dorsal portion ends just within the head. Its ventral portion is grooved and is continuous with the posterior wall of the aspiratory pharynx. Its distal extremity is slightly expanded, forming a stylet for piercing, while the little papillæ seen along the anterior surface in many species are absent in this one. Laterally there is a membranous expansion which interlocks with a similar expansion on the mandibles, forming a tube, through which the blood is sucked.

The mandibles are two in number, articulating just within the head, so that they are capable of independent movement. They are serrated at their distal extremities. Above, within the head, the anterior portion of the mandibles ends just behind the beginning of the hypopharynx, to which it is connected, becoming practically continuous with that organ. The posterior portion is attached to its basal element. Each mandible contains a groove, forming practically a closed canal, which becomes continuous with the exit duct of the salivary pump.

The rostrum (labial palpi) forms a protection and guide to the mandibles and epipharynx. Its first portion is unpaired and articulates within the head, with its basal element. At the apex of its first portion it bifurcates, forming a paired organ, which is divided into a varying number of pseudojoints, depending on the species of the flea. As it is a chitinous structure, these pseudojoints, areas in which there is little chitin, enable it to double up as the mandibles and epipharynx are inserted into the skin. At the apex of the rostrum are some tactile hairs.

The maxillæ are triangular chitinous plates situated on either side of that portion of the head where the biting organs emerge. These structures serve to protect the origin of the epipharynx and mandibles, rest upon the cutaneous surface in the act of biting, thereby steadying the head and serving as a fulcrum when the flea withdraws its biting apparatus when through feeding. The maxillæ have their palpi, which are four-jointed, paired organs coming out at the anterior lower angle of the head. Their function is sensory.

INSIDE THE HEAD.

The hypopharynx is a chitinous plate forming part of the floor of the aspiratory canal. To its under surface are attached the muscles which operate the salivary pump. Its lower portion is connected to the mandibles, while its upper portion is connected to the posterior portion of the floor of the aspiratory pharynx by a membranous ligament.

The aspiratory pharynx extends from the connection of the hypopharynx with the mandibles to the œsophageal commissure. In a general way it first passes upward and then turns, passing backward. Its roof is formed by the continuation of the ventral surface of the epipharynx, while its floor is formed by the hypopharynx below and above by the chitinous layer which is continuous with the œsophagus. The anterior end of this particular portion curves strongly downward, where it is attached to the upper portion of the hypopharynx by a membranous ligament. In a general way it may be divided into a vertical and longitudinal portion. The longitudinal portion expands laterally, so that its capacity is greatly increased when dilated. Into the floor of this longitudinal portion empties the vertical part of the aspiratory pharynx, and at the junction of the two there seems to be a valvular arrangement, preventing blood from escaping after it has entered the upper part of the aspiratory canal. The œsophagus starts at the œsophageal commissure and ends in the gizzard. It is

13429—10——9

not expanded as in some insects, forming a gullet, but is practically the same diameter throughout its entire extent. It is lined with chitin, surrounded by a delicate basement membrane.

The gizzard is a mushroom-shaped organ, opening into the stomach and receiving the contents of the œsophagus and the aspiratory pharynx. From its anterior concave inner surface project a number of finger-like processes that arise from a basement membrane. They are lined with chitin, and each one near its base contains an elongated nucleus. These processes reach to the center of the gizzard and in a general way point towards the opening into the stomach. The gizzard is surrounded by circular bands of muscle fibers. Its function is not entirely understood. Wagner (5) has pointed out that these processes may act as whips to defibrinate the blood. It is more probable that their action is mainly valvular, preventing regurgitation of blood from the stomach.

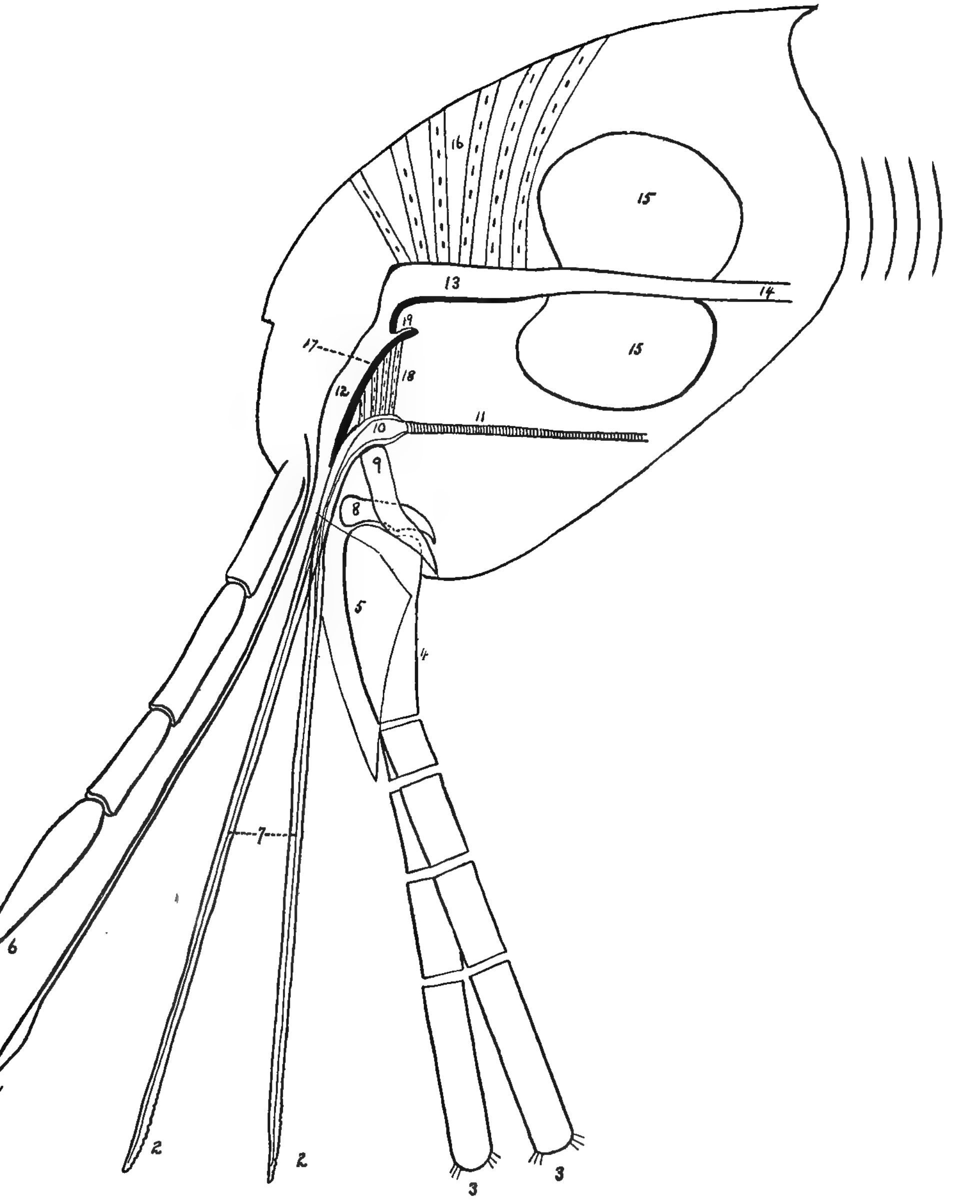
The stomach of a flea is large and is capable of great distention. It is composed of a layer of secretory cells, resting on a basement membrane, the organ being surrounded by muscle fibers passing in different directions. The epithelial surface is thrown into little projections like villi. As absorption occurs in the stomach, these villi, or projections of the epithelial cells, may serve to increase the absorptive surface as well as serving a glandular function. At the anterior end of the stomach are the cecal glands.

The intestine is short, receives the excretion from the Malpighian tubules, and ends in the rectum. In the rectum may be seen the so-called "rectal glands." All of the alimentary canal, with the exception of the stomach, is lined with chitin. The stomach and the rectum are capable of peristaltic movement.

The salivary glands, four in number, two on each side of the anterior part of the stomach, are simple acinous glands, lined with a single layer of secreting cells. The lumen of the glands is large and acts as a reservoir for the salivary secretion. The ducts from these glands unite to form a single duct which passes beneath the subœsophagal ganglion and empties into the salivary pump. This duct is lined on its inner surface by a spiral arrangement of chitin, giving it a very characteristic appearance.

DESCRIPTION OF FIGURE SHOWING MOUTH PARTS.

1. Epipharynx.
2. Mandibles.
3. Rostrum, paired portion.
4. Rostrum, unpaired portion.
5. Maxilla.
6. Maxillary palpus.
7. Salivary grooves.



MOUTH PARTS OF CERATOPHYLLUS FASCIATUS.

8. Basal element of rostrum.
9. Basal element of mandibles.
10. Salivary pump.
11. Salivary duct.
12. Vertical portion, aspiratory canal.
13. Longitudinal portion, aspiratory canal.
14. Oesophagus.
15. Oesophageal ganglia.
16. Muscles operating aspiratory canal.
17. Hypopharynx.
18. Muscles operating salivary pump.
19. Ligament connecting hypopharynx with floor of aspiratory canal.

THE ACT OF BITING.

The epipharynx, or pricker, makes an opening into the skin, through which the mandibles are inserted. These organs, by means of their serrations and independent movement, then enlarge the opening as with a saw, permitting them, with the epipharynx, to pass deeper and deeper until the points of the maxilla rest upon the cutaneous surface. The labial palpi serve as a protective case when the organs are not in action. When in action they serve as a guide to the piercing organs, but are not inserted into the skin. They double up like a bow, on each side, the bend of the bow becoming greater and greater as the biting apparatus passes deeper and deeper. Mitzmain (6) has pointed out that the spring-like action of this bow may assist the flea to withdraw the mandibles and epipharynx.

During the process of penetration the salivary pump receives saliva from the salivary glands and pumps it down, through the channel in the mandibles, into the wound. It will be seen that the hypopharynx, being attached above by a membranous ligament and connected intimately with the mandibles below, moves downward with these organs as they pass through the skin. At the same time the muscles attached to its under surface and the salivary pump contract, enlarging the lumen of the pump. When the mandibles are retracted the salivary pump collapses, thereby forcing the saliva out with the movement upward of the mandibles. At the proper time the muscles operating the aspiratory pharynx contract, drawing the canal open and aspirating blood through the canal made by the approximation of the epipharynx and mandibles and into the aspiratory pharynx. When full, the muscles relax from before backward and the pharynx, by means of the elastic reaction of its chitinous lining, contracts and forces the blood backward through the gizzard and into the stomach. It has already been pointed out that the finger-like processes in the gizzard probably act as valves to prevent regurgitation from the stomach.

HOW THE FLEA INFECTS ITS HOST.

The exact method by which the flea can transmit plague from animal to animal has, in our opinion, never been satisfactorily explained. There have been several explanations offered: First, that the rat may eat the flea. Miller (7) has found that the *Hepatazoon perniciosum* is transmitted from rat to rat through the rat eating the mite, *Lelaps echidninus*, which acts as the intermediate host. We know, however, that when a rat is fed on plague material a mesenteric bubo is the rule, while in naturally infected rats a mesenteric bubo is a rare condition. This, then, negatives the possibility of plague being contracted through eating the flea.

Another explanation is that the infection comes from the saliva injected at the time of biting. We have already stated that after repeated examinations, both by dissecting out the salivary glands and by serial sections of the entire flea, plague bacilli have never been demonstrated in these glands or anywhere outside of the alimentary tract.

Another explanation has been advanced, that the bacillus is introduced by the contaminated mandibles. It is not possible to exclude this as a means of infection, although the Indian Plague Commission made numerous investigations and was unable to demonstrate the bacillus on the mandibles.

The possibility of infection taking place by regurgitation from the stomach has also been considered. As the stomach is guarded by the finger-like processes in the gizzard which seem to act as competent valves, and as the movement of the blood aspirated by reason of the mechanism already explained is in a backward direction, it would seem improbable that there is any regurgitation from the stomach.

The most plausible explanation that has been advanced has been based on an observation that blood-sucking insects at the time of biting frequently eject a drop of blood from the rectum. We know that the rectum may contain numerous plague bacilli, and it is supposed that this blood ejected in the vicinity of the bite is either brought in contact with the slight wound by the feet or mandibles of the flea itself or is rubbed in as a result of scratching. Verjbitski has shown that an emulsion of the feces of fleas or any plague material when placed upon the bitten part before the expiration of twenty-four hours is sufficient to give the animal plague. After twenty-four hours the animals did not develop plague, it being supposed that the slight wound in the skin made by the biting apparatus had healed. It is probable that this ejection of blood is purely accidental and does not necessarily occur at the time of biting, but it is likely that the insect had just previously had a full meal, which had been digested and passed into the rectum. In the many biting experiments done by McCoy and Mitzmain they report never having seen this ejection of rectal contents taking place. It might also be stated that where they used plague-infected fleas none of the animals developed plague after being bitten.

ENUMERATION OF FLEAS THAT HAVE BEEN FOUND ON RATS.

Various writers have reported the following fleas taken off rats:

Family SARCOPSYLLIDÆ Taschenberg.

Genus DERMATOPHILUS.

1. *Dermatophilus cæcata* Enderlein.—Seventeen specimens (females) were found by Doctor Enderlein on the skin behind the ears of a specimen of *Mus rattus* from Saopaulo, Brazil.

Genus ECHIDNOPHAGA Olliff.

2. *Echidnophaga gallinacea* Westwood.—Tiraboschi has found this flea on the *Mus rattus* in Italy.

3. *Echidnophaga rhynchopsylla* Tiraboschi.—This flea has been taken in Italy from *Mus rattus* and *Mus alexandrinus*. It has been described by Rothschild under the name of *Echidnophaga murina*.

Family PULICIDÆ Taschenberg.

Genus CERATOPHYLLUS Curtis.

4. *Ceratopyhllus fasciatus* Bosc.—This is the common rat flea of Europe and the United States. It has also been found in Cape Town, Australia, and is occasionally found on rats in India.

5. *Ceratophyllus londiniensis* Rothschild.—This flea has been taken off mice in England; off rats in Italy (*Ceratophyllus italicus* Tiraboschi) and has been found once on *Mus rattus* in San Francisco, Cal.

6. *Ceratophyllus acutus* Baker.—This is the common flea of the California ground squirrel; and has been taken off *Mus norvegicus* in San Francisco, Cal.

7. *Ceratophyllus anisus* Rothschild.—This flea has been described by Rothschild from Yokohama, Japan, taken off *Felis* sp. One specimen was found in San Francisco, Cal., taken off *Mus norvegicus*.

8. *Ceratophyllus niger* Fox.—This flea is commonly found in San Francisco, Cal., in chicken yards and sparrows' nests and has also been found on rats, *Mus norvegicus*, and on man.

9. *Ceratophyllus consimilis* Wagner.

10. *Ceratophyllus lagomys* Wagner.

11. *Ceratophyllus mustelæ* Wagner.

12. *Ceratophyllus penicilliger* Grubè.

These fleas have been taken off *Mus norvegicus* in Europe.

Genus PULEX Linn.

13. *Pulex irritans* Linn.—This flea is widely distributed throughout the world, and while essentially the human flea has been found on many different species of animals and has frequently been encountered on rats. A very large number of specimens have been taken off rats in San Francisco, Cal.

Genus LOEMOPSYLLA Rothschild.

14. *Loemopsylla cheopis* Rothschild.—This is the common rat flea in tropical and subtropical countries. It has also been found in seaports of the temperate zone, where it has been brought by ship rats. Ninety-eight per cent of the rat fleas in India are of this species. It has been found in Australia, where it was described by Tidswell under the name of *Pulex pallidus*. In the Philippine Islands, where it was described by Hertzog as the *Pulex philippinensis*. It has been found in Brazil, where it was described by Baker as *Pulex brasiliensis*, and Tiraboschi has found it in Italy, where it has been described as the *Pulex murinus*. This flea has been frequently found on man in India.

Genus CTENOCEPHALUS Kolenati.

15. *Ctenocephalus canis* Curtis.—This is the common dog flea found in many parts of the world and is frequently taken off rats.

16. *Ctenocephalus felis* Bouché.—This is the common cat flea and is also a widely distributed species. Frequently taken off rats.

Genus CTENOPSYLLUS Kolenati.

17. *Ctenopsyllus musculi* Dugés.—In England this flea is commonly found on the domestic mouse. It has a wide distribution and has been found on rats and mice in Europe, South Africa, India, Australia, Mexico, and other places, and has been taken off *Mus norvegicus, Mus rattus,* and *Mus musculus* in San Francisco, Cal.

Genus NEOPSYLLA Wagner.

18. *Neopsylla bidentatiformis* Wagner.—This flea has been taken off *Mus norvegicus* in the Crimea.

Genus HOPLOPSYLLUS Baker.

19. *Hoplopsyllus anomalus* Baker.—This is one of the common groundsquirrel fleas of California and has been found on *Mus norvegicus* in San Francisco and Palo Alto, Cal. That these squirrel fleas are occasionally found on rats is interesting from the fact that plague has been demonstrated both in rats and the ground squirrel in California.

Genus HYSTRICHOPSYLLA Taschenberg.

20. *Hystrichopsylla tripectinata* Tiraboschi.—Reported by Tiraboschi from *Mus musculus* in Italy.

Genus CTENOPTHALMUS Kolenati.

21. *Ctenopthalmus agyrtes* Heller.—Taken off *Mus Norwegicus* in England.

The results of the identification of 19,768 fleas in San Francisco and Oakland, Cal.

SAN FRANCISCO, 1908.

Host: MUS NORVEGICUS.

Month.	C. fasciatus.		L. cheopis.		P. irritans.		Cten. musculi.		Cten. felis, Cten. canis.	
	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.	Male.	Female.
April to July 31	1,343	2,510	485	837	31	76	78	211	16	31
August	489	883	145	228	156	206	27	90	17	22
September	543	1,180	655	930	339	387	33	109	46	119
October	254	435	509	652	59	64	9	45	6	18
November	129	252	256	288	52	69	20	54	6	6
	2,758	5,260	2,050	2,935	637	802	167	509	91	196

Host: MUS RATTUS.

	23	43	3	3	0	0	17	16	1	0
	4	7	1	0	9	16	3	3	0	0
	27	50	4	3	9	16	20	19	1	0

Host: MUS MUSCULUS.

	4	10	1	0	0	0	2	10	0	0
	11	10	1	6	4	4	0	3	1	1
	15	20	2	6	4	4	2	13	1	1

OAKLAND, CAL, 1909.

Host: MUS NORVEGICUS.

February	135	304	166	178	1	1	229	506	1	3
March	253	456	167	215	2	5	125	243	1	2
April	227	479	105	129	0	1	62	143	0	1
	615	1,239	438	522	3	7	416	892	2	6

Host: MUS ALEXANDRINUS.

April	1	5	0	0	0	0	0	0	0	0

This does not include a few other specimens of different species taken from *Mus rattus* and *Mus norvegicus*, which have been included under the heading of "Enumeration of fleas which have been found on rats."

SYNOPSIS OF FLEAS COMMONLY FOUND ON RATS.

A. WITHOUT A COMB OF SPINES ON THE PROTHORAX OR THE HEAD.

1. Two bristles on the gena, an ocular bristle placed below the eye, an oral bristle placed just above root of maxilla. Mesothorax not divided by an internal incrassation. Claspers in male forming prominent hump, claw like and covered by hairy flap. An irregular row of about 10 teeth on inner side of hind coxa .... *Pulex irritans.*
2. Two bristles on gena, an ocular placed in front of and just above middle of eye, an oral bristle placed just above root of maxilla. Mesothorax divided by internal incrassation, claspers not forming prominent hump, not claw like, not covered by hairy flap. A regular row of about six teeth on inner side of hind coxa, *Lœmopsylla cheopis.*

AA. WITH A COMB OF SPINES ON PROTHORAX BUT NOT ON HEAD.

3. Three bristles on lower genal row, upper genal row represented by three or four small bristles running along anterior margin of antennal groove. Eye present, about five hairs on second joint of antenna, not as long as third joint. Maxillary palpi not as long as labial palpi. Labial palpi reach to apex of fore coxa. Spines on posterior tibia in pairs of about five groups. Head of male flattened on top, *Ceratophyllus fasciatus.*

AAA. WITH A COMB OF SPINES ON THE PROTHORAX AND ON THE HEAD.

4. Eye present, seven spines on lower margin of gena. Spines on posterior border of tibia in pairs .... *Ctenocephalus canis* or *felis.*
5. Eye absent, four spines on hind margin of gena. Spines on posterior tibia single and in a close-set row .... *Ctenopsyllus musculi.*

DESCRIPTION OF PLATE II.

Fig. I. Clasping organs of male ....
- P .... Process.
- F .... Finger.
- M .... Manubrium.
- IX St .... Ninth Sternite.

Fig. 2. Head of female.

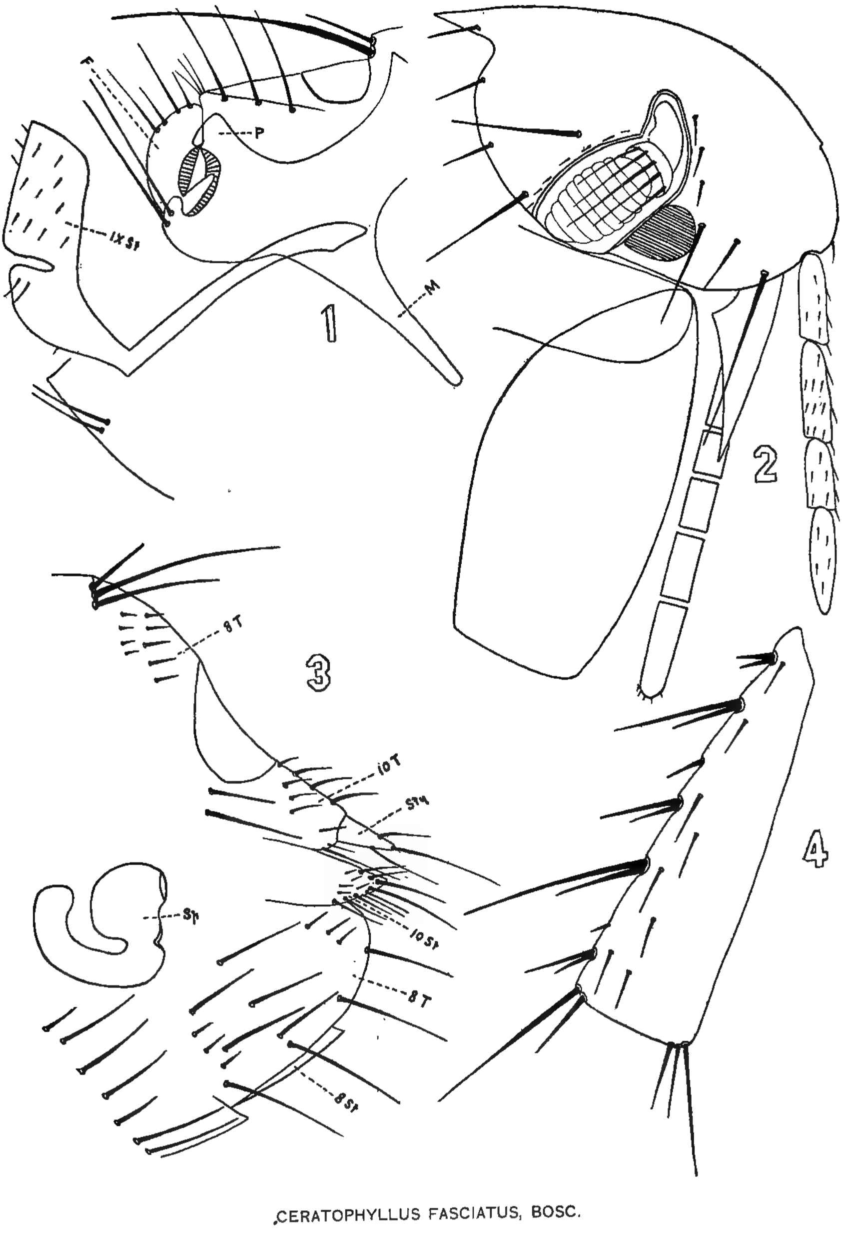
Fig. 3. Terminal abdominal segments, female ....
- 8 T .... Eighth Tergite.
- 8 St .... Eighth Sternite.
- 10 T .... Tenth Tergite.
- 10 St .... Tenth Sternite.
- Sp .... Spermatheca
- Sty .... Stylet.

Fig. 4. Hind tibia.

CERATOPHYLLUS FASCIATUS Bosc.

[Plate II.]

Head.—Evenly and gently rounded in the female, flattened on top in the male. Frontal notch distinct. Eye present, placed low down in head. Gena acutely pointed posteriorly. Maxilla triangular.



CERATOPHYLLUS FASCIATUS, BOSC.

Maxillary palpi not as long as the labial palpi. Labial palpi reach to apex of anterior coxa, 5-jointed. Antennal groove in the male reaches to top of head, in the female to within one-third. There are 3 bristles on the lower genal row, the middle of which is the smallest, while the upper genal row is represented by 3 small bristles, extending along the edge of the antennal groove. In the male the lowermost bristle is frequently paired. There are several fine hairs above the eye. The occiput contains the normal row of apical bristles, the lowest of which is the largest. There is one bristle back of the middle of the antennal groove and a number of fine hairs along the posterior margin of the antennal groove. The antenna is 3-jointed, the first joint contains a row of about 5 very short fine hairs, while the second joint contains about 5 not as long as the third joint.

Thorax.—The pronotum has one row of about 10 bristles, and a ctenidium composed of about 16 or 18 spines. The mesonotum has a posterior row of about 10 long bristles and there is an anterior row of more numerous smaller ones. The metanotum has also a posterior row of about 10 large bristles, with an anterior row of more numerous smaller ones, while still anterior to this there are 5 or 6 still smaller bristles. The metathorax contains 8 or 10 bristles which are small anteriorly, larger posteriorly. On the sternum of the metathorax there are 2 large bristles, while the episternum has 3 smaller ones. On the epimerum are 2 bristles placed anteriorly and 3 or 4 posteriorly, one of which is on the apical margin.

Abdomen.—The first stigma is nearly in line with those of the other abdominal segments. There are two rows of bristles on the abdominal tergites, a posterior of about 12 or 14 and an anterior of smaller, less numerous bristles. The antipygidial bristles in the female are 3 in number on each side, of which the middle is the longest, and the inner one the smallest. The male has but 2 antipygidial bristles on each side. The sternites from the third to the sixth have a single row of about 10 bristles, while the seventh has about 12. The metanotum has 2 teeth on each side, as have the first and second abdominal tergites. The third and fourth abdominal tergites have 1 tooth on each side.

Legs.—The fore coxae are normally clothed. The fore femur has on the outer side 11 or 12 fine bristles irregularly disposed, while on the mid femur there is a row of about 3 to 5 bristles on the inner surface. The hind coxa has no patch of spines on the inner side, while on the inner surface of the hind femur there is a row of about 5 to 7 bristles. The spines on the posterior tibia are in pairs of six groups, while on the outer surface there is a row of about 7 bristles. None of the apical bristles of the tarsi are as long as the next succeeding joint. The fifth tarsal joints on all the legs have 5 lateral spines.

Length of joints of tarsi:

Mid tarsi (♂)	8	7	4½	3	7
Hind tarsi	18	11	7	4	8
Mid tarsi (♀)	8	7	5	3½	7
Hind tarsi	21	13	8	5	8

Modified segments.—(♂). The manubrium of the claspers is straight and narrow, while the process extends upward as a short, blunt cone, where at the tip there are several fine hairs. The lower margin is evenly and gently rounded. The finger is short, extending but a little above the process. It is concave on its anterior surface and convex on its posterior, and from the posterior margin there are 2 large and 2 small bristles alternating. Two long heavy bristles arise from the process below the insertion of the finger. The ninth sternite is broad, with a deep sinus in its posterior border. Its lateral surface contains numerous fine hairs, these hairs being somewhat larger just beneath the sinus. Along the dorsal border of the tenth sternite there are 3 heavy bristles in line. At the tip of the tenth tergite there is one heavy bristle. Besides these heavy bristles in this segment there are numerous fine hairs.

(♀) The eighth tergite contains just anterior to the sensory plate about 12 small hairs while just beneath the sensory plate there are 2 long bristles. Lower down there is a patch of about 6 bristles and on the apical margin 4 to 6. The stylet is short, cylindrical, slightly larger at the base than at the tip, where there is a long bristle. On the under surface arises a fine hair. Substylar flap (tenth sternite) has along its margin numerous hairs.

Description of Plate III.

Fig. 1. Clasping organs of male:
- P............Process.
- M............Manubrium.
- F............Finger.
- IX St.......Ninth Sternite.

Fig. 2. Head of female.

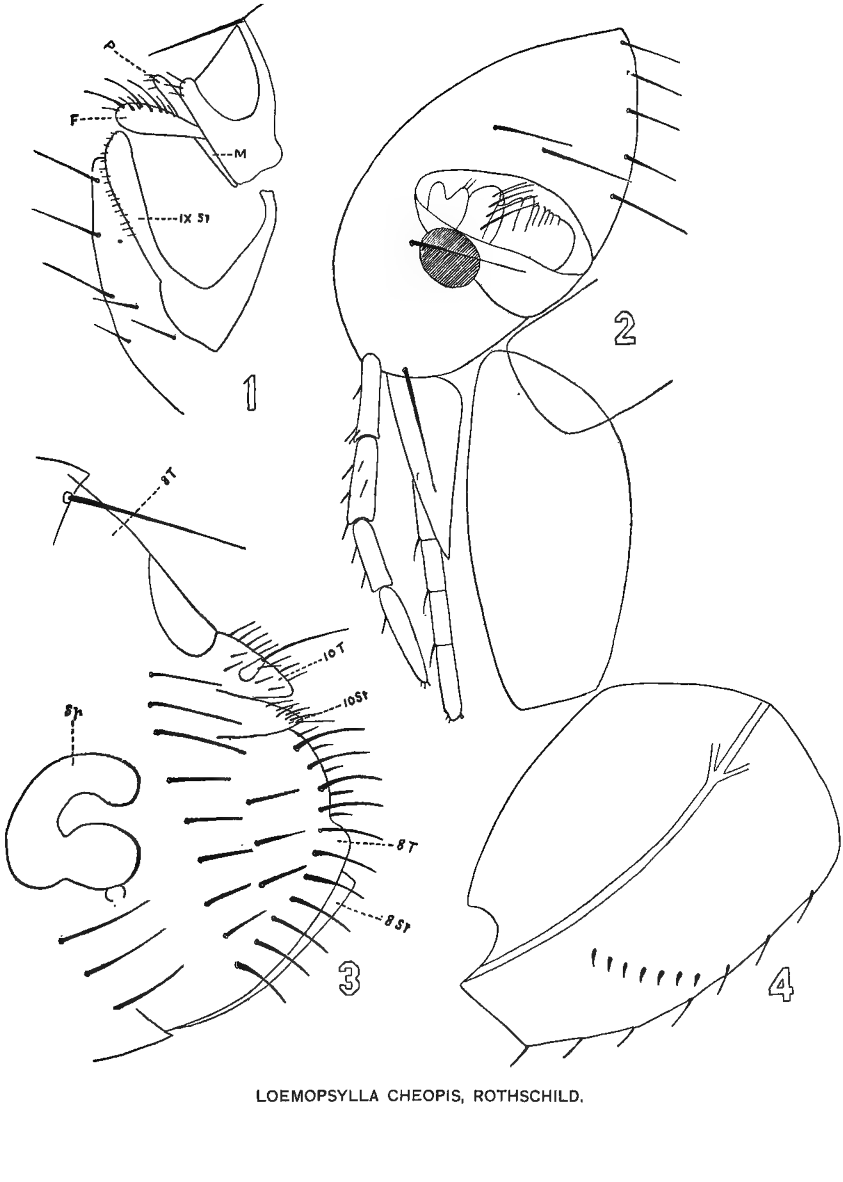
Fig. 3. Terminal abdominal segments, female:
- 8 T..........Eighth Tergite.
- 8 St.........Eighth Sternite.
- 10 T.........Tenth Tergite.
- 10 St........Tenth Sternite.
- Sp...........Spermatheca.

Fig. 4. Hind coxa inner surface.

LŒMOPSYLLA CHEOPIS Rothschild.

[Plate III.]

Head.—Abruptly rounded. Flattened on top in ♂. Eye present. No ctenidia on head. Antennal groove in the ♀ reaches to within one-third of the top of the head. In ♂ reaches to top of head. Gena obtusely pointed posteriorly. Maxilla triangular. Maxillary palpi are not as long as labial palpi. Labial palpi reach to apex of



LOEMOPSYLLA CHEOPIS, ROTHSCHILD.

fore coxæ, 4-jointed. Anterior edge of antennal groove overlapped by chitinous flap. On posterior edge of antennal groove are a number of small bristles, these being most distinct in the male. The first antennal joint in the male contains 4 or 5 hairs at its outer edge, while transversely there is a row of several fine hairs. The second joint has a row of fine hairs not as long as the third joint. Divisions marking separations of third joint most pronounced on dorsal edge. Two bristles on gena. The oral bristle placed low down just above the base of the maxilla; the ocular bristle in front and just above the middle of the eye. Six bristles on the posterior margin of the occiput on each side with 2 back of the antennal groove.

Thorax.—The pronotum is without a ctenidial comb, and has one row of about 14 bristles. The mesonotum, the broadest of the three thoracic nota, also has a single row of about 12 bristles. The metanotum has a single row of about the same number. The mesosternite contains about 5 bristles. The pleura of the metathorax is normally divided. The sternum contains 2 bristles, 1 anterior and 1 posterior. The episternum contains 1 bristle, and the epimerum contains 2 rows of bristles, an anterior row of 7 and an apical row of the same number.

Abdomen.—The first abdominal tergite contains 2 rows of bristles, an anterior and a posterior of about 6 bristles each, while the next 6 contains but a single row of about 14 bristles each, the lowest placed just below the stigma. From the seventh tergite springs a single antipygidial bristle. The sternites contain a single row of 8 or 10 bristles.

Legs.—The fore coxa is normally clothed. The fore femur has on its outer surface about 8 fine bristles. The mid femur has a single row of about 6 bristles, while the hind femur has a row of the same number. The hind coxa has on its inner surface a regular row of about 6 teeth. The hind tibia has on its posterior border 5 groups of spines in pairs, while on its outer surface there are about 8 small bristles in a row. The apical bristle on the second tarsal joint of the hind leg reaches to about the middle of the fifth tarsal article. The fifth tarsal article on all of the legs has 4 lateral spines and a subapical pair of hairs.

Modified segments.—(♂) The manubrium of the claspers is short and narrow. There are two free processes, the upper one, the finger, being broadest and wider at the tip than at the base, its upper border being more convex than the lower border and containing a number of bristles. The ninth sternite is club-shaped, is nearly straight on its dorsal margin, and the ventral margin contains a row of fine bristles from base to apex.

(♀) No bristles in front of the sensory plate. Along its apical margin externally there is a row of about 12 long bristles, and internally a row of less numerous, shorter bristles. Laterally there is a more or less regular row of about 8 bristles, and between this row and the apical row 3 or 4 more.

DESCRIPTION OF PLATE IV.

Fig. 1. Clasping organs, male:
- 10 T........Tenth Tergite.
- 10 St........Tenth Sternite.
- P...........Process.
- F...........Finger.
- M...........Manubrium.
- IX St.......Ninth Sternite.

Fig. 2. Head of female.
Fig. 3. Last tarsal joint of hind leg.

Fig. 4. Terminal abdominal segments, female:
- 8 T..........Eighth Tergite.
- 8 St.........Eighth Sternite.
- 10 T.........Tenth Tergite.
- 10 St........Tenth Sternite.
- Sp..........Spermatheca.

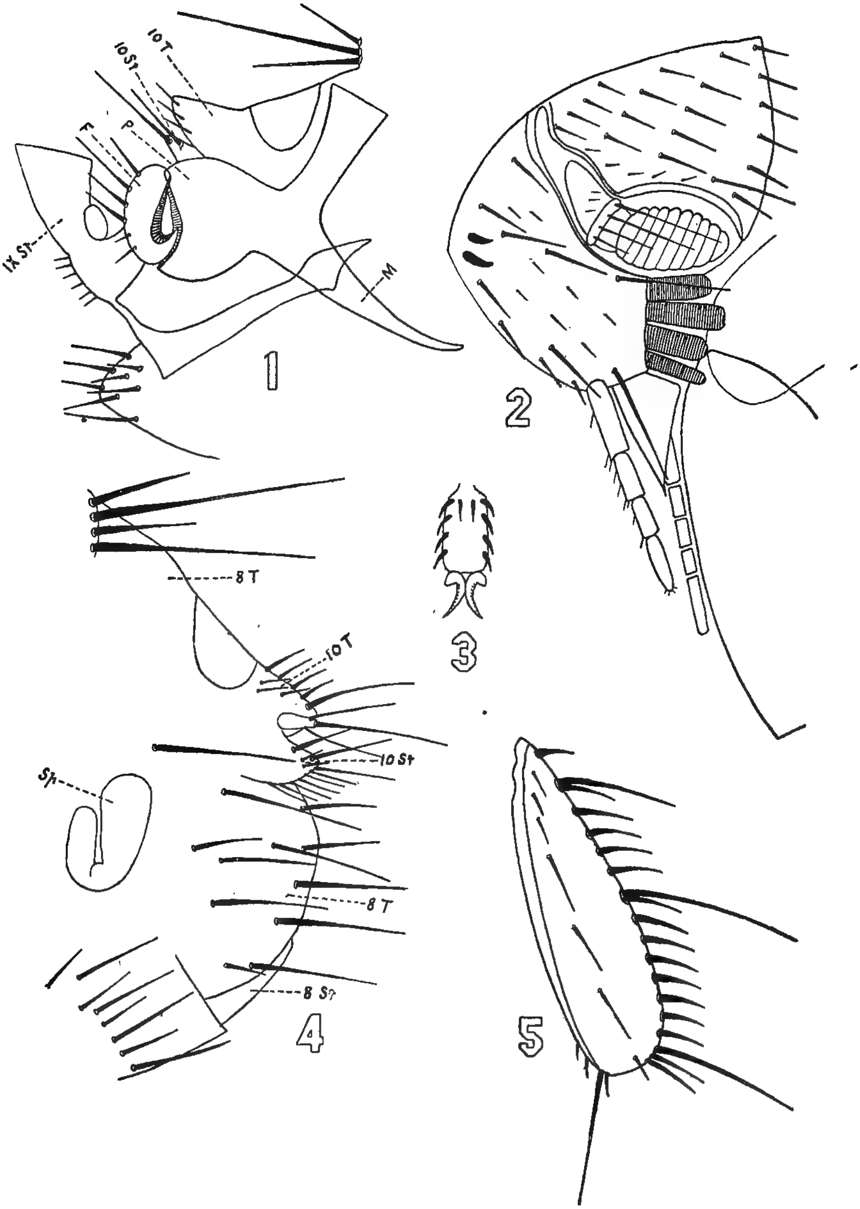
Fig. 5. Hind tibia.

CTENOPSYLLUS MUSCULI Dugés.

[Plate IV.]

Head.—The frons is prominent anteriorly, giving the head somewhat the shape of a fez. There are 4 spines on the posterior border of the gena. The antennal groove reaches to the top of the head. The maxillary palpi are shorter than the labial palpi, which reach to about two-thirds of the fore coxa and are 5-jointed. Maxilla triangular. Eyes absent. At the most prominent part of the frons anteriorly there are two short thick spines, while below these, running along the anterior margin, there are 5 bristles. Above there is an oblique row of 4 bristles, with 1 more placed near the top of the antennal groove. Between this oblique row and lower bristles there are numerous fine hairs. On the occiput there is a subapical row of about 7 bristles on each side, while in front of this are 3 oblique rows of bristles, the first containing 3, the second 4, and the third 5. On the posterior margin of the antennal groove there are several small hairs. On the first joint of the antenna there are about 3 hairs, while on the second joint there are 4 or 5, the longest somewhat longer than the third joint.

Thorax.—The pronotum has an anterior row of about 10 bristles, and a ctenidium of about 24 spines. The mesonotum contains about 4 rows of bristles, more or less regularly disposed, each row consisting of about 8 or 9 bristles. The metanotum has 2 rows of bristles, a posterior row of about 10 bristles, and an anterior of the same number, while there are several smaller bristles in front of this. The mesothorax contains about 10 bristles. The episternum of the metathorax has 2 bristles, and on the sternum there is 1 large one.



CTENOPSYLLUS MUSCULI, DUGES.

The epimerum has 2 rows of 4 bristles each, with 1 large one at the the apical margin.

Abdomen.—The first abdominal tergite has 2 rows of 10 bristles each, the posterior being comprised of the larger bristles. The next 6 tergites have 2 rows of bristles each, a posterior of large bristles, about 12 in number, and an anterior of smaller bristles, also 12 in number. On the apical edge of the metanotum there are 2 small teeth on each side. The first abdominal tergite contains 3 such teeth while the second and third have 1 each on each side. At the apex of the seventh tergite in the female there are 4 antipygidial bristles, sometimes 5. The male has but 3 antipygidial bristles. The abdominal sternites from the third to the sixth have a single row of 6 bristles. The seventh has a row of about 16 bristles.

Legs.—The fore coxa has about 32 large bristles more or less regularly disposed in 6 oblique rows. The hind coxa is without teeth on the inner surface. The mid femur is without bristles on its lateral surfaces. The hind femur is also without a row of bristles on its lateral surfaces. The spines on the posterior border of the tibia are single and in a close set row. The apical spines of the second tarsal joint of the hind legs are shorter than the third joint. The last tarsal joint on all the legs contains 4 lateral spines and a subbasal pair situated between the first lateral pair.

Modified segments.—(♀) Just beneath the pygidium is 1 long bristle. On the eighth tergite there is a patch of hairs, 6 of which are on the apical margin and about 5 or 7 anterior to these. The stylet is short, almost as wide at the base as at the tip, where there is a long hair. Posteriorly to this bristle there springs another one from the under surface.

(♂) Manubrium of the claspers is narrow, curved at the tip. The finger reaches to the level of the process, has a stout pedicle, is flat on its anterior border, and is decidedly convex on its posterior border, where there are 4 bristles. The shape of the ninth sternite is shown in the figure.

DESCRIPTION OF PLATE V.

Fig. I. Clasping organs of male........................
- P............Process.
- F............Finger.
- M............Manubrium.
- IX St.......Ninth Sternite.

Fig. 2. Head of female.

Fig. 3. Terminal abdominal segments, females.........
- 8 T..........Eighth Tergite.
- 8 St.........Eighth Sternite.
- 10 T.........Tenth Tergite.
- 10 St........Tenth Sternite.
- Sty.........Stylet.
- Sp..........Spermatheca.

Fig. 4. Hind coxa, inner surface.

PULEX IRRITANS Linnæus.

[Plate V.]

Head.—Evenly and abruptly rounded in both sexes. Frontal notch absent. Eye large. Maxillary palpi longer than the labial palpi. Labial palpi reach to about half the length of the anterior coxa and are 4-jointed. The mandibles are broad and markedly serrate. Maxillæ triangular. Antennal groove short and wide, closed behind, thickened on edges, and reaches to top of head in both sexes by chitinous thickening. Second joint contains 8 or 9 fine hairs, shorter than the third joint. Division of the third joint only to be seen on dorsal surface. Two bristles on the gena, one placed low down just above the maxilla, the other below the eye. From the lower margin of the gena occasionally may be seen a small tooth. One bristle on the occiput near the posterior lower angle. A few fine hairs on the posterior edge of the antennal groove.

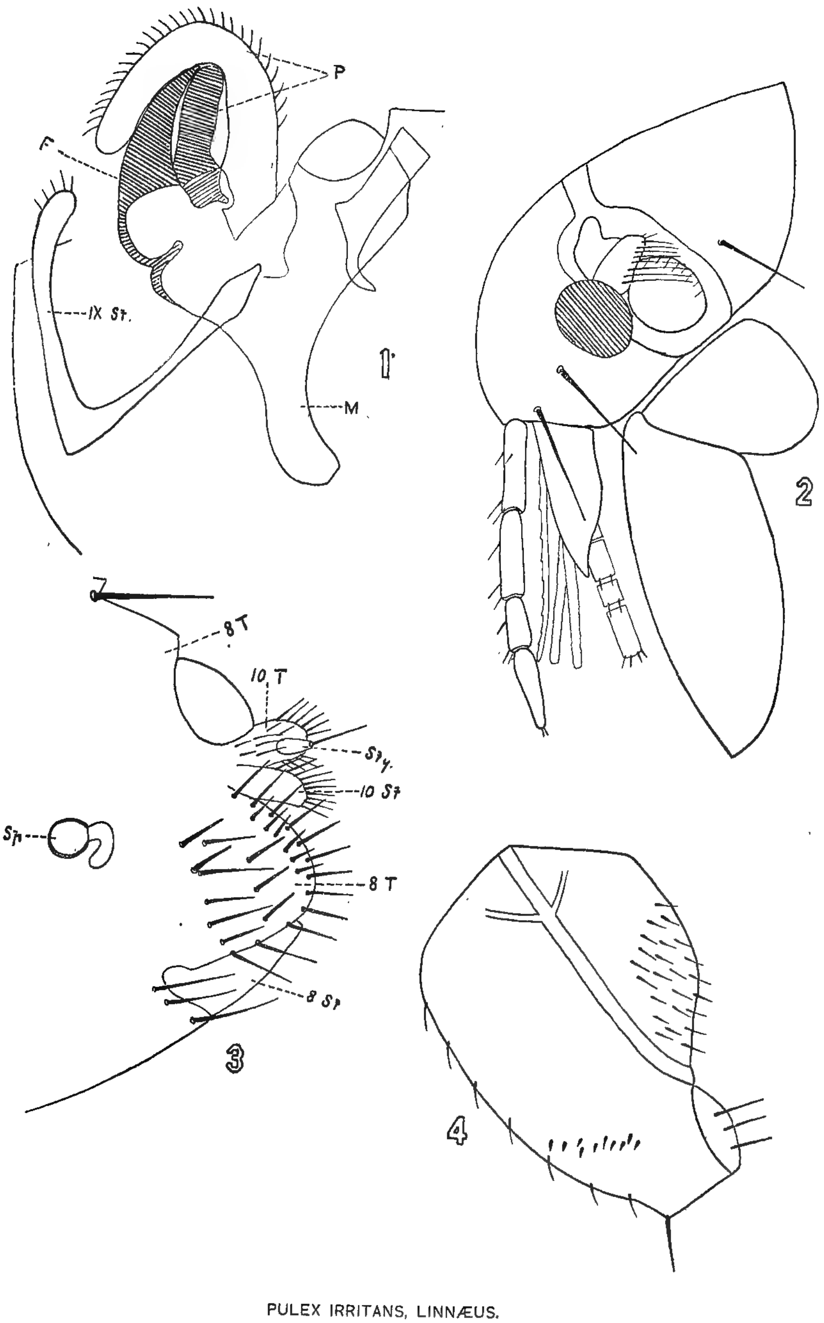
Thorax.—The thoracic nota each contain a single row of about 10 or 12 bristles. There is no ctenidium on the pronotum. The mesosternite is narrow and is not divided by an internal incrassation. The episternum of the metathorax is large and contains about 2 or 3 bristles and is not quite separated from the sternum anteriorly. The epimerum has an anterior row of about 7 or 8 bristles and an apical row of about 6.

Abdomen.—Each of the abdominal tergites, with the exception of the first, has a single row of 8 or 10 bristles. The first has 2 rows of about 4 each. The sternites from third to seventh have a single row of about 6 bristles. There is one short antipygidial bristle on each side.

Legs.—The hind coxa has on its inner surface posteriorly a number of fine hairs, while anteriorly there are 10 or 12 teeth in an irregular line. The hind femur has on its inner surface a row of about 8 or 9 bristles. The spines on the posterior tibia are in pairs, and there are about 7 bristles in a line on its outer lateral surface. The apical bristle of the second tarsal joint of the hind leg reaches to about the middle of the fifth joint. The last tarsal joints of all the legs contain 4 lateral spines and a subapical pair, and between the third and last lateral spine there is a hair.

Modified segments.—(♀) The eighth tergite has no bristles above the pygidium but has numerous short stout bristles laterally and on and close to the apical margin. The stylet is short and stout and has at its tip a long hair. The tenth sternite and tergite contain numerous fine hairs, those on the sternite confined to the apical edge.

(♂) The male claspers are quite characteristic. The manubrium is large and curved and points ventrally. The claspers have two processes, the lower of which, with the finger, form together a kind



PULEX IRRITANS, LINNÆUS.

of claw which is covered by the other process forming a flap, quite hairy on its upper margin. The ninth sternite is described very well by Rothschild (8) as "boomerang" shaped. The eighth tergite has a small manubrium.

DESCRIPTION OF PLATE VI.

Fig. 1. Clasping organs of male.......................{F...........Finger. M...........Manubrium. IX St.......Ninth Sternite.}

Fig. 2. Head of male.

Fig. 3. Terminal abdominal segments, female........{8 T..........Eighth Tergite. 8 St.........Eighth Sternite.}

Fig. 4. Hind coxa and femur, inner surface.

CTENOCEPHALUS CANIS Curtis.

[Plate VI.]

Head.—Strongly and evenly rounded in both sexes. Eye large. Maxilla triangular. Maxillary palpi about as long as labial palpi. Labial palpi reach to two-thirds of anterior coxæ, 4-jointed. Seven spines along the lower margin of the gena. The posterior angle of the gena ends in a small tooth. Occasionally this may be absent. Antennal groove in the female reaches to within one-third of the top of head and is prolonged upwards by a chitinous thickening and in the male reaches almost to top of head. Two bristles on the gena, one placed well toward the anterior lower angle and the other in front of the eye. Usual number of bristles on posterior margin of the head, with 2 large ones back of the antennal groove. About 8 hairs on the second joint of the antenna nearly as long as the third joint.

Thorax.—A row of about 10 bristles on the pronotum, with a ctenidium of about 14 to 16 spines. Two rows of bristles on the mesonotum, a posterior of about 12, another of more numerous smaller bristles placed well anteriorly. The metanotum contains a single row of about 10 or 12 bristles. The episternum of the metathorax has 3 or 4 stout bristles, while the epimerum contains an anterior row of about 10 bristles and a posterior row of about 9.

Abdomen.—The first abdominal tergite contains 2 rows of about 4 bristles each, while the other tergites to the seventh contain a single row of from 12 to 16 bristles. The stigmata are large. There is a single antipygidial bristle on each side. The sternites from third to seventh have a single row of 4 bristles each.

Legs.—The hind coxa has on its inner side a patch of from 6 to 12 spines, while the hind femur has a row of 10 or 12 bristles on its inner surface. The spines on the posterior border of the hind tibia, with the exception of the apical, are in pairs, while in the apical group are about 3 stout bristles. The apical spine of the second joint of the hind leg reaches to nearly the middle of the fifth joint. On the fifth joint of all the legs there are 4 lateral spines and a subapical pair, and between the third and fourth lateral spines there is a hair.

Modified segments.—(♀) The eighth tergite has no hairs back of the stigma. The apical margin is rounded at the apex and contains 8 or 10 bristles. The stylet is short and wide and contains at its tip a long and a short bristle.

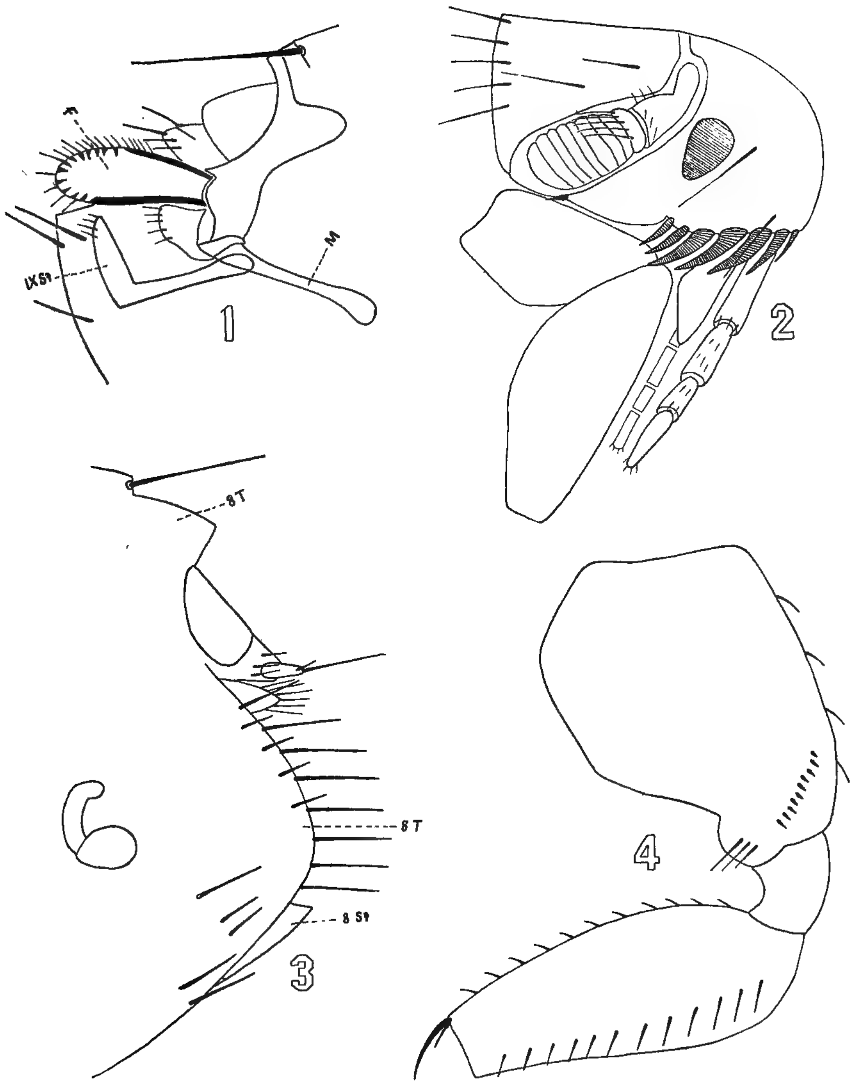
(♂) The manubrium is short and narrow. The movable finger of the clasper is short, thick, swollen at its middle, bluntly rounded at its extremity, and contains on its upper border numerous hairs and a few on its lower border.

Rothschild (9) has pointed out certain differences between the *Ctenocephalus canis* and *Ctenocephalus felis*. The differences are that in the female of the felis the head is longer and more pointed. This difference is not so pronounced in the male. Also certain differences in the shape of the claspers and the number of bristles in the episternum and epimerum of the metathorax and the hind femur, those in the *C. canis* being more numerous. Also that group of bristles on the posterior border of the hind tibia between the fifth pair and the apical bristles consists of two in the *Ctenocephalus canis*, while there is but a single bristle with a small hair in the *Ctenocephalus felis*.

REFERENCES.

1. 1909, McCoy.—"Plague Bacilli in Ectoparasites of Squirrels." Public Health Reports, Vol. XXIV, No. 16.
2. 1908, Schumann.—"A Disease of Rats Caused by Mites." Centralblatt f. Bact., Oct. 30th.
3. 1909, McCoy and Mitzmain.—"An Experimental Investigation of the Biting of Man by Fleas Taken from Rats and Squirrels." Public Health Reports, Vol. XXIV, No. 8.
4. 1908, McCoy.—"A Report on Laboratory Work in Relation to the Examination of Rats for Plague at San Francisco, California." Public Health Reports, Vol. XXIII, No. 30.
5. Wagner.—Aphanipterologische Studien aus dem zootomischen laboratorium der Universitat zu St. Petersburg.
6. 1908, Mitzmain.—"How a Hungry Flea Feeds." Entomological News, December.
7. 1908, Miller.—"Hepatazoon Perniciosum (N. G. N. SP.). A Hæmogregarine Pathogenic for White Rats; With a Description of the Sexual Cycle in the Intermediate Host; A Mite (Lælaps Echidninus)." Bull. No. 46, Hyg. Lab. U. S. Pub. Health and Mar. Hosp. Serv., Wash.
8. 1908, Jordan and Rothschild.—"Revision of Non-Combed Eyed Siphonaptera." Parasitology, Vol. I, No. 1.
9. 1901, Rothschild.—"Notes on Pulex canis, Curtis, and Pulex felis, Bouché." Entomologist's Record, Vol. XIII, No. 4.

   1905, Rothschild.—"Some Further Notes on Pulex canis, Curtis, and Pulex felis, Bouché." Novitates Zoologicae, Vol. XII.



CTENOCEPHALUS CANIS, CURTIS.

RODENTS IN RELATION TO THE TRANSMISSION OF BUBONIC PLAGUE.

By Surgeon Rupert Blue,
United States Public Health and Marine-Hospital Service.

Man has associated the rat with bubonic plague since the dawn of history. The monuments and coins of the earliest times yield abundant evidence of this association. Æsculapius, the god of the healing art, is represented by the Greeks with a rat at his feet. An early scriptural reference may be found in the first Book of Samuel in the fifth and sixth chapters. The historian records therein the occurrence of a fatal epidemic of "emerods" in the land of the Philistines coincident with an invasion of "mice."

The inhabitants of southern China in recent times have learned to look upon the finding of sick and dead rats in their homes as a harbinger of evil, in fact, as a forerunner of that dread scourge—"wan-yick," or plague. In the villages and cities of the Kwantung and Kwangsi provinces, as recorded by medical missionaries, epizootic plague almost invariably precedes an outbreak among human beings. So well is this fact known to the common people that many seek safety in flight, feeling assured that in a short time "yang-tzu" or "wan-yick" will claim a harvest of victims among those who remain.

Doctor Mahē, sanitary officer for the port of Constantinople, in 1889, called attention to the fact that epidemics of plague were always announced by a great mortality among rats and mice. In 1894 Yersin reported the fatal epizootic among rats then prevailing in Canton and Hongkong coincident with the outbreak of plague among the Chinese. Recent researches have confirmed these observations and a great deal has been added to the literature of plague, especially in relation to its mode of transmission. Indeed, it should be said that wherever the disease has prevailed in recent years the relation of rats to its spread has been observed, and that since the discovery of the specific bacillus by Yersin and Kitasato, in 1894, bacteriological investigations have shown that there is no difference morphologically or culturally between the bacilli of human and rat plague.

Moreover, the gross and microscopic lesions in the lymph nodes are practically the same, and the *B. pestis* recovered in both fulfills the postulates of Koch.

Nothing was definitely known, however, of the mode of transmission of the disease from rat to rat or from rat to man until the completion of the experimental work of the Indian Plague Commission. Simond, Ogata, Thompson, and Koch each expressed the belief that the infection was transferred by the rat flea. Nuttall (1897) and Simond (1898) demonstrated the presence of *B. pestis* in the bodies of bugs (*Cimex*) and fleas which had been taken from plague-sick rats, and the latter observer, in the same year, succeeded in transmitting the disease from rat to rat without contact.

The work of the Indian Plague Commission was undertaken (1905) with a view to establishing the exact relationship between epizootics among rats and epidemics among men, and included both field and laboratory observations. The experiments of Gauthier and Raybaud (1903) and of Simond were repeated on a larger scale and greatly improved in that all rats and fleas used were first identified as to species. The findings of the commission may be briefly summarized as follows: That fleas and bugs taken from plague-sick rats contain *B. pestis*, and that some of them remain alive in the bodies of the insects from five to sixteen days; that plague is conveyed by the bites of fleas which have previously fed on the blood of animals suffering with the disease; that rat fleas bite man; that under experimental conditions the infection is not transferred from rat to rat in the absence of fleas.

A careful study of the findings of the workers in India justifies the assumption that plague is a disease of the rodent primarily and accidentally, and secondarily a disease of man. An analysis of the epidemiological facts collected in San Francisco leads to the same conclusion. As a result our practice with regard to suppressive measures and quarantine procedure has undergone a radical change in the last decade. If the infection is flea-borne from rat to man in the majority of cases, then the extermination of the rat should be the first principle upon which to base a campaign. In the former contribution on the subject (1907) I stated that "if we destroy the host there is no longer danger of infecting the parasite." This basic principle has been recognized and successfully applied in two campaigns against plague in San Francisco. First in the outbreak in Chinatown in 1903–4, and again in the larger epidemic of 1907.

The outbreak of 1907 began May 27, 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. The source of infection was, in all probability, a recrudescence from a focus which was not destroyed in the campaign of 1903–4. There occurred 160 cases with 77 deaths, the last case appearing January 30, 1908. The following table shows the incidence of human plague:

Year.	Cases.	Deaths.
1907.		
May	1	1
August	13	6
September	56	25
October	34	25
November	41	12
December	13	7
1908.		
January	2	1
Total	160	77

EPIDEMIOLOGICAL OBSERVATIONS IN SAN FRANCISCO.

Abundant epidemiological data associating the rat[a] with plague have been collected in San Francisco. For the purpose of illustration a detailed reference to a few cases will be made. Two small boys (October, 1907) while playing in an unused cellar found the body of a dead rat. The corpse was buried with unusual funeral honors. In forty-eight hours both were ill with bubonic plague. A laborer finding a sick rat on the wharf picked it up with the naked hand and threw it into the bay. He was seized three days later with plague. Doctor C. and family lived in a second-story flat over a grocery store in the residence section. Being annoyed for some days by a foul odor the doctor caused the wainscoting around the plumbing to be removed. One or two rat cadavers were found in the hollow wall. In two or three days the two members of the family who used the room sickened, one dying on the fifth day of cervical bubonic plague. It is probable that infected rat fleas were set free by the removal of the wainscoting.

Dead rats were frequently found in or near houses where plague had occurred. Immediately upon the discovery of a case of plague trained men were sent into the neighborhood and a thorough search made for rats. This work consisted in the removal of defective wooden floors and walls of insanitary buildings and other harboring places. Extensive rat catacombs were frequently found in these operations. In the yard of a house in which 4 cases had occurred 20 cadavers were found under the board covering. In the walls of a Chinese restaurant 87 dead rats were uncovered.

[a] *M. norvegicus* and *M. rattus*.

Very little can be said of the relation of mice (*M. musculus*) to the epidemic. While many thousands were trapped, only a few hundred were examined microscopically and in these no infection was found. They are nonmigratory in habit and for this reason are not considered of much importance from an epizoological standpoint.

Transmission from man to man was observed in but a small percentage of cases, 3 per cent to be exact. In these the probability of transference by fleas (*P. irritans*) or by bugs (*Cimex*) must be admitted. When more than one case occurred in a house a common source of infection was indicated, such cases occurring simultaneously or within from forty-eight to seventy-two hours after the first. Deratization was the measure mainly relied upon. After an infected house was rat-proofed, and the harboring places in the block destroyed, no further cases occurred.

The course of epizootic plague was not interrupted an any time by climatic conditions, there being as many cases in proportion to the rat population in the winter of 1908 as there were at the height of the epidemic. The last case of human plague occurred January 30, 1908, but the infection remained active among rats for eight months longer, or until October 21, 1908. (See following table.)

Month.	Number examined.	Number infected.	Per cent.	Average temperature.	Rainfall in inches.	Character of days.
1907.				°F.		
September	1,002	27	2.69	60.6	0.11	Clear, 13. Part cloudy, 15. Cloudy, 2.
October	2,679	23	.86	60.6	1.36	Clear, 10. Part cloudy, 10. Cloudy, 11.
November	3,954	36	.88	57.8	.04	Clear, 14. Part cloudy, 13. Cloudy, 3.
December	4,308	48	1.11	52.4	3.66	Clear, 6. Part cloudy, 11. Cloudy, 14.
1908.						
January	6,622	70	1.05	50.8	4.88	Clear, 5. Part cloudy, 11. Cloudy, 15.
February	11,700	45	.38	51.0	5.39	Clear, 11. Part cloudy, 12. Cloudy, 6.
March	19,263	52	.26	54.8	.90	Clear, 20. Part cloudy, 10. Cloudy, 1.
April	15,524	34	.21	56.3	.22	Clear, 17. Part cloudy, 10. Cloudy, 3.
May	11,311	20	.13	55.4	.76	Clear, 17. Part cloudy, 12. Cloudy, 2.

Month.	Number examined.	Number infected.	Per cent.	Average temperature.	Rainfall in inches.	Character of days.
1908.				°F.		
June	13,624	4	0.02	55.3	0.01	Clear, 16. Part cloudy, 9. Cloudy, 5.
July	11,204	2	.017	57.4	.02	Clear, 11. Part cloudy, 17. Cloudy, 3.
August	10,988	0	.0	57.3	.01	Clear, 11. Part cloudy, 10. Cloudy, 10.
September	15,902	0	.0	59.3	.29	Clear, 16. Part cloudy, 9. Cloudy, 5.
October	10,178	2	.019	58.8	.061	Clear, 16. Part cloudy, 7. Cloudy, 8.

The rats examined for September, 1907, were very largely collected from the badly infected districts; the remaining months give a truer picture of the extent of the epizootic in the entire rat population.

THEORIES AS TO THE CAUSE OF SEASONAL PREVALENCE.

The marked seasonal prevalence of plague in man in San Francisco may be given as additional proof of the association of the rat with its spread. In the cold, rainy season, from December to April, the epidemic ceases while the epizootic is apparently not influenced. The anomaly is accounted for when we remember that the rat and its parasites are very susceptible to cold and rain. It is then that the animal seeks a warm, comfortable place from which it does not venture until driven thence by dire necessity. In other words, the association of the rat with man is not so intimate in winter, while the reverse is true of the relation of rat with rat. The rains, while interrupting the overground migrations and domiciliary visits of rats, drive them to overcrowded burrows and harboring places. Another factor should be mentioned in this connection. Human fleas (*P. irritans*), and probably rat fleas also, are markedly reduced in numbers at that season of the year. We must conclude, therefore, that the seasonal prevalence of plague in man is due to the effect of climatic conditions upon the habits of rats and the life history of the insect carriers of the bacilli.

An examination of the foregoing should convince everyone that all former theories as to the prolonged viability of *B. pestis* in contaminated soil or in polluted streams, and of the periodical spread of the infection therefrom, are no longer tenable. It may also be stated that insanitary conditions, except in so far as they furnish food and shelter to rats and other vermin, play no important

13429—10——11

rôle in the continuance of plague. This general revision has also eliminated overcrowding as an important factor. In the absence pneumonic cases, and of suctorial insects, this *bête noire* of the sanitarian may be disregarded.

THE OCCURRENCE OF PLAGUE IN THE MARMOT OF ASIA AND THE GROUND SQUIRREL OF CALIFORNIA.

Rudenko (1900) first pointed out the possibility of contagion by the "Tarbagan," a species of the *arctomyinæ* found in Siberia. He observed a connection in 1894 between this rodent and an outbreak of plague in a Cossack family of Soktuewsk. According to Beliatsky and Zabolotny, each having been an observer in the same field, the natives of Siberia and Mongolia often acquire plague in this manner. Le Dantec and other writers have called attention to the probable susceptibility of the marmot (*Arctomys bobac*), a hibernating rodent of India and China. The marmot of Thibet, in the opinion of this writer, is the natural animal host and purveyor of the virus. The literature of the subject presents no bacteriological evidence, however, of such a relationship, and plague in the *arctomyinæ* of Asia is merely an hypothesis. There is positive evidence though of the susceptibility of the tree squirrel (*Sciurinæ*) to plague infection. Dr. Alice Corthorn (1898) reported the finding of a plague-infected squirrel in one of the outbreaks in the Bombay Presidency.

PLAGUE INFECTION IN GROUND SQUIRRELS.[a]

The demonstration of natural plague in the California ground squirrel (*Otospermophilus beecheyi*) is perhaps the most important observation of the antiplague work of the service in 1908. The existence of a plague epizootic in Contra Costa County was suspected as early as the summer of 1903, and efforts were made at that time to collect sick and dead rodents for bacteriological examination. In August (1903) two fatal cases of human infection occurred in widely separated sections of the county. The investigation which followed failed to connect either with a previous case of human plague, but showed an association with ground squirrels. These deaths occurred during a fatal epizootic among ground squirrels and suggested a connection which unfortunately was not confirmed.

None of the circumstances were forgotten, however, and in the second campaign, begun in September, 1907, in San Francisco, inspectors were detailed to examine all persons dying in the area under suspicion. No plague was reported that autumn and winter. Fatal cases occurred and were reported by the inspectors in July, 1908, as follows: A boy (J. F.) died July 15, near Concord, and a young

---

[a] Genus Citellus, Oken; subgenus Otospermophilus. "California Mammals," Frank Stephens.

woman (M. P.) died July 28, on a ranch 10 miles from Martinez. The two were not associated. An investigation was ordered at once and a force of trappers was hurried to the scene with instructions to collect squirrels from the ranches in the vicinity. The first plague-infected squirrel was found August 5 on the ranch where the boy had died July 15. Of 425 squirrels collected from August 1 to October 12, 4 showed the gross and microscopic lesions of natural plague.

A lad (F. M.) sickened August 5, 1908, in Los Angeles, Cal., after being bitten by a sick ground squirrel. A polyadenitis, which afterwards proved to be plague, developed in a few days. A dead squirrel was found nearby and pathological specimens taken from it were sent to the United States Plague Laboratory in San Francisco. McCoy recovered *B. pestis* from the tissue of the animal. This was the only case of plague reported in Los Angeles. In order to complete the list of those who contracted plague in the country, two other cases should be mentioned. F. S., a pregnant woman, died of bubo-septicæmic plague near Concord, Cal., February 29, 1904. The *B. pestis* was recovered in pure culture from the axillary glands. In April, 1906, a school boy of east Oakland developed a multiple plague adenitis. Investigation showed that he had shot and handled ground squirrels in the country four or five days before his illness.

THE NATURAL HABITAT OF PLAGUE.

The location of the natural habitat of plague has concerned sanitarians for many years: Not a few have settled upon India as the endemic center, while others associate China with the epidemics which have devastated Europe from remote times. Le Dantec, a recent writer, suggests the "lofty mountains" between India, Thibet, and China as the exact location, and selects the rodent (marmot) of that region as the natural enzootic host.

A panzootic leaves in its wake enzootics of plague in various countries which persist until the rodents upon which they thrive are either exterminated or rendered immune. At varying intervals epidemics spring from them and finally cease with the exhaustion or destruction of the enzootic foci. Plague disappears in time from these temporary abodes and retires to its original habitat in India or China.

Of serious import in this connection is the fact that all the conditions necessary for the establishment of a permanent focus of plague exist on the Pacific coast of the United States. The broad valleys and lofty mountains of this region are rich in the *arctomyinæ*, there being no less than 12 species in California alone. In the high Sierras the marmot (*Marmota flaviventer*),[a] a species of the natural enzootic host of Le Dantec, is found in great numbers. The ground squirrel infests the valleys and foothills in an unbroken chain from Ore-

---

[a] "California Mammals," Frank Stephens.

gon to the Mexican border. Once planted in this ideal soil, infection may never be uprooted or its growth and extension controlled. Small outbreaks will occur here and there, and periodical visitations of greater magnitude may be expected in cities where a combination of epidemiological factors is permitted.

The facts as set forth in this paper have caused grave apprehension in the minds of those who have been at all conversant with the conditions in the transbay counties since 1903. At that time the writer recognized the probability of the establishment of a permanent focus of plague in that locality, and subsequent discoveries have proven the correctness of the assumption. This changes the aspect of the problem from that of a local infection to one of national importance. Once established in such a rural community, plague is dislodged with difficulty and only after a campaign covering a considerable length of time. Being a national problem it can be best solved by the Federal Government.

REFERENCES.

The Croonian Lectures on Plague, W. J. Simpson; Journal of Hygiene, Volume VI, No. 4; Volume VII, No. 6; Volume VIII, No. 2; Plague among the Ground Squirrels of California, W. B. Wherry, Journal Infectious Diseases, Volume V, No. 5; California Mammals, Frank Stephens.

RODENT EXTERMINATION.

By Passed Asst. Surg. William Colby Rucker,
United States Public Health and Marine-Hospital Service.

It should be remembered that rodents are extremely wily creatures and that any campaign against them is a contest between the wit of man on the one hand and acute animal instinct on the other. The rat, by his constant association with man, has become extremely wary, and is frightened by anything in the least out of the ordinary. They will eat the bread on which poison is spread so carefully that they will leave behind the poison and take practically all the bread; they will open traps by pressing down the pan, and they have been known to repeat this operation several times within an hour, entering the trap, eating the bait, and then liberating themselves. At other times they will enter the trap and stand on the pan with their hind legs, eat the cheese, then carefully turn around and back out. This, of course, is not possible with snap traps, but they have been known to spring them by causing pieces of wood to fall upon them, after which the bait would be eaten. Rats are found wherever food exists in abundance or where they can find suitable breeding and nesting places.

Rodent extermination is a problem, with difficulties arising from the animal's highly developed regard for self-preservation. In main, the rat requires two conditions for life. He needs plentiful food and places suitable for nesting and breeding. Eliminate either of these elements and you drive away your rats. Yet the problem remains far more difficult than shown in the simple terms of the above equation. The fabulous speed at which rats multiply will baffle all but the most determined and efficient efforts to exterminate them. Under normal conditions each female bears 3 litters a year and each litter produces 10 young. Under conditions ideally favorable, it has been computed that 1 pair of rats will in five years, providing all can live so long, increase to 940,369,969,152. Such a result is, of course, impossible in nature, for it means that every rat born of the original pair survive five years; that every litter of 10 contains 5 males and 5 females; and that the ideally favorable conditions persist. On the other hand, rodent existence is an unending struggle in which an enormous percentage succumbs; the ratio of half males and half females does not hold; and ordinary conditions of life are hardly even favorable. Nevertheless, the above proves emphatically that no rat eradication can be effective unless the breeding is curtailed. Any campaign against rodents must aim (*a*) to slaughter the greatest possible number of those already living and (*b*) to prevent the possibility of further breeding.

The existing rats are best attacked by trapping, by poisoning, and by their natural enemies. Traps and poisons alone have been found insufficient to keep pace with the rat's speed of multiplication. The surest of the rat's enemies are his natural ones, and once they have been loosed upon him his chance of escape is reduced. The cat, dog, skunk, and other rodent foes, given a fair chance, quickly drive out rats. But these animals do not eradicate the pest. The rats will probably migrate to some other shelter, returning when their natural enemies have quieted down. Absolute extermination is reached only when conditions make the continuation of species impossible for the rat.

The size and frequency of rodent litters decreases proportionately with every cutting off of food supples. Separate the rat from his pabulum and he will not breed so freely nor so often as when he is well fed. Destroy rat habitations and make it impossible for them to find new nesting places, and breeding will virtually cease, since the unsheltered progeny can no longer survive, and since the starving parent rats are driven to cannibalism in the struggle for existence.

Campaigns against rodents must cover five directions: (1) Trapping, (2) poisoning, (3) exposing them to natural enemies, (4) cutting off food supply, and (5) destroying existing nests at the same time that the making of new ones is prevented.

Parenthetically, it may be noted that while these principles apply equally to the extermination of rats in cities and in country districts, their application must vary according to the place.

TRAPPING.

The kind of traps to be used varies with the rodent to be captured and the locality which it infests.

CAGE TRAPS.

The large 19-inch French cage trap gives good results where rats are plentiful. It should be made of stiff, heavy wire and well reenforced, as a large, strong rat will force his head between the wires in a weak trap and thus escape. Before setting, the lever on the trap should be tested to see that it works properly. The trap should be placed on a hard surface, with the rear end a little higher than the entrance, so that the trap will close promptly. When setting the trap in the open it should be fastened to a board on which about an inch of soft dirt has been spread. Place the trap where the rat usually goes for food or in a runway and disturb the surroundings as little as possible. It is sometimes well to place the trap near where there is dripping water, as the rats come there to drink. If the trap is set in hay or straw or wood it should be covered (with the exception of the entrance) with this material. When this is not possible it should be covered with a piece of sacking or placed in a dark corner or beneath the floors. When setting the traps in the sewer a dry place should be chosen.

The rat is more or less of an epicure, therefore the bait should be changed at frequent intervals. Also he should be given food which he is not in the habit of getting. For example: In a meat market vegetables are the best bait, while in a location where vegetables are plentiful fresh liver and fish heads, or a little grain, are best. The following may be suggested as good bait to be used: Fish, fish heads, raw meat, cheese, smoked fish, fresh liver, cooked corn beef, fried bacon, pine nuts, apples, carrots, and corn. When trapping in chicken yards a small chick or duckling is remarkably good. When a large number of rats are caught in one trap, search for the female and leave her alive in the trap, as she may call in the young or the males. The bait should be fastened to the inner side of the top of the trap with a piece of fine wire so that the first rat in can not force the bait underneath the pan and thus prevent the entrance of other rats. A few grains of barley should be scattered near the entrance of the trap and a small piece of cheese or meat fastened to the pan with a piece of wire. It is often well to touch the pan with a feather which has been dipped in oil of anise or oil of rhodium. Before leaving the trap it should be smoked with a piece of burning newspaper to kill the smell of the human hands or the rats which have been in it. Do not handle the trap after burning it out. When trapping in a neighborhood where rats are known to exist the traps should not be moved for three or four days unless they have rats in them, as it is well for the rats to become accustomed to seeing them and thus careless about entering. It is not wise to kill rats where they are caught, as the squealing may frighten the other rats away.

SNAP TRAPS.

Snap or spring traps are best for use in houses and stores, with the exception of fish and meat markets. Snap traps are best for use in runways, beams, and shelves. It is sometimes well to disguise the trap by covering its floor with a little sawdust or dirt. They should be first tested to see that they work properly and that the staples are secure. New traps should be smoked or stained to render them an inconspicuous color.

The bait should consist of some firm material, such as fried bacon or tough meat, and should be tied on so that the rat will be obliged to pull on it and thus spring the trap. The trap should be placed in a corner or close to the wall on a flat, hard surface, so that the rat can not spring it with his tail or by walking on it.

BARREL TRAPS.

In warehouses and granaries large numbers of rats may frequently be trapped by using a barrel or garbage can having a metal top which is carefully balanced. Large pieces of strong cheese are placed in the middle of the cover and a plank laid from the floor to the edge of the barrel. The rat runs up the plank onto the smooth metallic lid which tips and the rat is precipitated into the barrel.

In cities trapping is one of the most effective of the three methods to slaughter rodents. The rat highways are easily discovered and in them traps capture great numbers of the unwary. In the country one can not so readily determine the rat highway. This difficulty diminishes the effectiveness of trapping. To make up for what is thus lost shooting has been resorted to with good results. In Honolulu, where a vigorous campaign against rodents is being waged, a very large proportion of the captured rats (*Mus rattus* and *M. alexandrinus*) have been shot from trees. In Contra Costa County, Cal., where ground squirrels are being exterminated, it has been found that rodents possess an instinctive suspicion of traps and that during the summer months shooting is not only the most practical but also about the only effective means of attacking them. Shotguns are the weapons to use. A rifle requires the hunter to be a better shot than is ordinarily obtainable for such work, and, furthermore, the danger from its longer range and from ricocheting bullets menaces cattle and farm hands who may be working in the vicinity. As to the shot and the powder charge for shells hunters differ. It is a different problem for every shotgun, depending upon the gun's caliber and choke. The principle is to put the greatest number of the largest shot the gun will carry into the rodent body. Thus in 10 and 12 gauge guns shoot No. 8 shot and in 16-gauge guns shoot No. 9 shot, but this varies with each individual gun. The use of soft lead or chilled shot seems a matter for personal preference. The charge must be as much as the gun will carry. In the country smokeless powder becomes a necessity during summer months since black powder is liable to ignite the dry grass and stubble.

POISONING.

PLASTER FLOUR.

Plaster flour is prepared by mixing one part dry plaster of Paris with two parts flour or meal. When this is taken in sufficient quantity by the rodent it produces death by the formation of enteroliths, death occurring in from four to eight days. This is a poison of uncertain value and is recommended chiefly on account of its cheapness and small danger to children and domestic animals. It can not be used in wet weather, and judging from the small number of rats found dead with plaster casts in the alimentary canal it is not believed to be very efficacious.

PHOSPHORUS PASTE.

Phosphorus paste is prepared by mixing crude phosphorus in the proportion of one-half to 10 per cent in a suitable base. The latter may consist of cheese, sugar, and oil of anise mixed together and heated to the consistency of sirup, the phosphorus being added after the fire has been withdrawn and the mixture begun to cool. Other bases are cheese, corn meal, and oil of rhodium; cheese, ground fish, or meat and oil of valerian, glucose, and a small quantity of flour. Glucose makes an exceptionally good base, as when properly mixed the poison thus prepared is noninflammable even when heated. The liability to spontaneous combustion of phosphorus mixtures eliminates their use in hay, grain, or other warehouses or places where there is danger of fire or the invalidation of insurance. It should not be forgotten that phosphorus deteriorates very rapidly, especially when it is exposed to the sun.

ARSENIC PASTE.

This consists of arsenious acid combined with a base of cheese, meal, or macerated fish. It may be placed on raisins or prunes and is to be recommended on account of its stability, the ease with which it is handled, and the absence of danger from fire. It should, however, be distributed with great care, every percaution being used to place it where it is inaccessible to children and domestic animals.

BARIUM CARBONATE.

This has not proven an effective poison owing to the fact that it is easily decomposed by the vegetable acids, especially lactic and oleic acid found in cheese and oil. The poisonous effect is not greatly altered by this change. A disagreeable metallic taste is produced and the rats will not take it.

STRYCHNINE.

Strychnine is prepared as a poison by soaking wheat over night in water and subsequently pouring off the excess fluid and placing the wheat in a caldron containing hot glucose and strychnia sulphate, the latter in the proportion of one-tenth of 1 per cent. After carefully stirring so that each grain is thoroughly coated it is dried in shallow iron pans over a slow fire with constant agitation of the grain, or by exposure on sheets or canvas to the rays of the sun. This mixture may be made much more efficient by the addition of cyanide of potassium in the proportion one-half of 1 per cent. Poisoned grain has not been found efficient in the destruction of rats, as its bitter taste causes them to eat little or none of it. It is, however, particularly efficient in poisoning squirrels, as it is taken readily by them. The chief objections to its use are its cost, difficulties of preparation, and liability to its being taken by chickens.

CARBON BISULPHIDE.

Carbon bisulphide is not a poison so much as an asphyxiant. As the name indicates, it is a two-to-one mixture of sulphur and carbon. The resulting liquid preparation should be kept in air-tight cans, since it evaporates quickly. The principle of its efficacy against rodents is that the fumes are heavier than air and, sinking into a rat or squirrel hole, drive out the necessary oxygen. To use bisulphide saturate a small pad of some absorbent cotton, jute, wool, or flannel material with the liquid, thrust this into the rodents' burrow, and carefully stop all apertures through which the fumes might escape. Animal life of every sort in that burrow is quickly asphyxiated. In buildings the use of carbon bisulphide is greatly hampered by the difficulty to confine the gas by stopping all cracks and other openings. Also the odors of decomposition in animals so killed stand against its use anywhere but in the country.

Against rats and squirrels in country places carbon bisulphide has proved one of the best of all weapons. Where it kills, it kills whole families at a time, not one by one, as must ever be the case with other poisons and with traps or shotguns. Not only does it kill the rodent but it also destroys the rodent's fleas and vermin, which is most important. A dead infected rat is still a menace, since its fleas may inoculate other rats and human beings with the infection. Destroy the fleas and that greatest danger is removed. The recent campaigns against rodents in the United States have been waged because rats and squirrels were infected with bubonic plague; hence the added value of carbon bisulphide. Unfortunately, though this asphyxiant proved so effective in the work against squirrels in Contra Costa County, Cal., it proved to be well-nigh useless during the summer season when dry heat checks the adobe and makes the ground generally porous. Nevertheless, the value of carbon bisulphide, especially for sanitary purposes, can not be easily overestimated for work in the country during the fall, winter, and spring seasons.

Fumigants in general are effective. They possess no marked or peculiar advantages as special weapons against rodents. Their use is limited chiefly to warehouses, elevators, and ship holds. They are deadly to rats in the same way that they are fatal to every sort of life. Many difficulties and some dangers stand in the way of their use. It is safe to advise that no one unacquainted with their action should ever employ fumigants.

NATURAL ENEMIES.

The war upon rats carried on in San Francisco has proved the great value of cats and dogs as natural enemies of the rat. That city now has a law requiring all structures of 800 or less square feet and outside certain limits to be raised high enough above the ground to allow access to cats and dogs. (All other buildings in the city must be rat proof.) An index to the worth of rodent foes in their extermination points from what happened during the great London plague. At that time the disease was supposed to be air carried; any furry material might hold and spread infection. The magistrates decreed that all cats and dogs should be killed to prevent plague from lodging and traveling in their hair. Rats were thus free to live and breed unmolested, and live and breed they did until the plague killed them off; then and then only did the disease cease its ravages among human beings.

DOGS.

Slight training will make excellent ratters of Fox, Irish, or Scotch terriers. Fox terriers have proved especially valuable as retrievers when shooting squirrels, which in one case out of five will escape to their burrows unless sharply retrieved.

CATS.

Cats are little less valuable than dogs against rats, while they are useless against squirrels. The ordinary cat is too well fed to attack large rats and goes, almost solely, after mice.

All other animals naturally preying upon rodents class with wild life—weazels, ferrets, badgers, skunks, and minks. These can be used only in country places, where, however, their raiding of chicken coops tends to counterbalance their value as ratters. The skunk alone is an infrequent slayer of fowl, whereas he harvests innumerable farm pests from worms to crickets. Yet an insurmountable prejudice against skunks stands in the way of realizing his full usefulness against rodents. In addition, various hawks and most owls kill off rats. Since rats come out chiefly in the nighttime, owls have the better chance to be serviceable in their destruction. The efficiency of these birds in rural districts quite equals that of a dog against rats, while besides dogs we have not as yet found a safe natural foe of ground squirrels.

But all such attacks upon rats fail of absolute eradication. One must make it impossible for them to find sustenance and must destroy not only all existing rat houses, but also all chance of their digging or finding new ones.

CUTTING OFF THE RAT'S FOOD SUPPLY.

This is important not alone for its effect in a campaign upon rodents, but equally because it necessitates sanitary care and cleanliness in handling foodstuffs intended for humans and garbage coming therefrom. Abattoirs and places where cattle and hogs are fattened perhaps furnish the greatest number of rats. Stables, food-supply stores, groceries, meat, fish and vegetable markets, restaurants, bakeries, and the various places where food is prepared for human consumption are usually infested. In each of the places the barriers vary according to the nature of the premises. Rat-proof receptacles for the foodstuffs must be installed wherever practical. In San San Francisco an ordinance requires every stable to have metal lined feed bins. Markets and places where eatables are constantly being shifted about must be properly screened against rats. Screening should be of heavy wire and sufficient fineness, not larger than half-inch mesh. In all places the food has to be raised such a height above floorings as to be beyond the rat's reach. This applies also to corn and grain cribs in the country. Yet, no matter how carefully the bulk of the food may be kept from rats, negligence in handling it, in spilling or scattering small amounts upon floors or the ground, will nullify every precaution.

No less painstaking must be the disposition of garbage. Ordinance now requires that all premises in San Francisco be provided with "sanitary garbage cans." Preferably these should be of zinc or galvanized iron and fitted with tight covers. Under no circumstances should the cover be allowed to remain off its can. Garbage is to be placed in a can without delay and care must prevent the dropping of it upon the ground. Rats once served communities as scavengers; wherever the scavenger work is laxly done, rats are welcomed. Finally, garbage must never be allowed to accumulate and should be removed daily, not less often than every other day.

Special conditions, closely related to the next topic, are encountered in large warehouses and grain sheds. Places where large quantities of food may be stored for a length of time should be constructed of reenforced concrete to be rat proof. Then, again, where vessels are changing cargoes, rat-proof compounds should be erected for the temporary storage of freights. The water fronts of seaports are invariably rat ridden; and in San Francisco a compound for freight held in transit was found invaluable. No effort can be spared in keeping rats from their food if their extermination is to be accomplished.

With regard to ground squirrels, the use of poisoned wheat very properly enters here. With the changing season ground squirrels change their habitat and food. During early spring these rodents come down from their winter dwellings in the hills and seek burrows in meadow lands and cultivated spots. Months have passed since the squirrel tasted wheat; his fickle appetite betrays him. From the first spring months until harvest time one can kill thousands of ground squirrels by tempting them with poisoned wheat. But so soon as harvest time comes, they seek new growing green stuffs to eat and thereafter, on through winter, poisoned wheat is ineffective.

BUILDING THE RAT OUT OF EXISTENCE.

Most certain of all methods to get rid of rodents is to allow them no place in which to live. San Francisco effects this result through its ordinance, which requires small houses outside certain city limits to be raised so high from the ground that dogs and cats can drive out rats from under them, and which requires all other buildings in the city to be rat proofed with cement or concrete. The latter contemplates foundation walls of concrete or brick sunk at least 1 foot to 18 inches to 2 feet above that surface; the whole ground area inclosed by their foundation walls must be covered with concrete at least 1½ inches in thickness. Thus the entrance of burrowing rodents is prevented. Even where buildings stand upon rock or hardpan, these requirements should be enforced. Rock may crack, gradual weather decay may cause crevices to be found in it unseen crannies may be found by rodents, and once the rat lodges in rock his nest is virtually unassailable. With hardpan it is even worse, for the rats can burrow in it, with some difficulty, truly, but when nests are impossible elsewhere, necessity will drive rats to find shelter in hardpan, which will protect them quite as well as rock. In the main, these two points of building rats out of existence, though modified, will apply to any structure.

Yet any negligence will overthrow these safeguards. The principle is to allow no opening within which rodents may nest. Plank sidewalks and back yards will continue the rat nuisance even though buildings are amply protected. Carelessness in throwing old boxes into basements or piling old lumber or refuse within reach will supply shelter for rats despite concreted ground area. The precaution must be constant and consistent.

Another important phase is to cut off the rodent migrations. Prevent rats from moving from place to place. Their time-honored highway is through sewers. Modern sewers afford no protection, inviting rodents to live in them as formerly. Scarcely less important, access should be stopped. Catch-basin feeding sewers should be constructed so that rats can not slip through into the mains, or having once gotten in, they can not escape, and hence must drown. Farms are frequently protected against rodent migrations by tin or zinc sheeting sunk into the ground about a foot and a half and standing about the same height above the surface along the fence line.

Finally, as the progress of rodents from place to place within communities must be hindered, so must they be stopped from entering new communities. Railroads and seagoing vessels carry great numbers of rats in freight. The rat-proof compounds above described serve well enough so far as railroads are concerned. With vessels it is a different matter, and one demanding special attention, since the rodent is only too likely to import infection from foreign harbors. All hawsers thrown out to make boats fast should be provided with traps to catch any rat seeking to land along the hawser. San Francisco, about to possess a rat-proof water front, is now building concrete wharves to prevent the landing of rodents. Every port should be safeguarded by stone, concrete, or iron wharves and piers. As a further protection, all ships should have permanent devices, as is now proposed for naval construction. Levy's system of metal conduits built into vessels promises much in the present world-wide war upon rodents. Rodents must be "built out of existence," and to eradicate rats for all time we must erect wide systems of municipal fortifications.

NATURAL ENEMIES OF THE RAT.

By David E. Lantz,
Assistant Biologist, United States Department of Agriculture.

INTRODUCTION.

Undoubtedly the great increase of rodent pests throughout North America is in large part due to a general scarcity of the animals that habitually prey upon them. Since the early settlement of the country persistent warfare has been made on birds and mammals of prey on the plea that they are enemies of poultry, game, and insectivorous birds. Efforts to destroy the predaceous birds and mammals have been greatly stimulated by the payment of municipal, county, and state bounties, and the destruction has gone on until in many sections these animals have nearly disappeared.

The effect of killing off the natural enemies of rodents has been to disturb natural conditions. Rodents multiply so rapidly that they derive an undue advantage in the struggle for existence when their natural enemies are destroyed. The result is noticeable in the increased depredations of rats, field mice, rabbits, and other pests.

The destruction of carnivorous wild mammals and birds by the farmer, hunter, or game preserver is often due to misapprehension. Because one kind of hawk preys on the farmer's poultry is not sufficient reason for exterminating all hawks. Nor does the fact that occasionally an owl or a skunk destroys a chicken or a game bird justify warfare on all owls and skunks. It is the occasional individual and not the species that offends.

ANIMALS THAT DESTROY RATS.

The usefulness of the natural enemies of the rat must not be overlooked in plans for its repression. Among the more important are the larger hawks and owls, skunks, foxes, coyotes, weasels, minks, and a few other wild mammals; as well as cats, dogs, and ferrets among domestic animals, and snakes and alligators among reptiles.

HAWKS.

Most of the larger hawks destroy rats. Feeding only in the daytime, they seldom find their quarry near houses and barns, where rats do not venture out until after sunset. Besides, owing to persecution by farmers, hawks generally keep away from farm buildings. In the open fields, however, where rats feed in early morning and late afternoon, hawks find many of the rodents.

The species of hawks that more commonly feed on rats are the buzzard hawks, including the red-tailed (*Buteo borealis* and subspecies), the red-shouldered (*B. lineatus*), the broad-winged (*B. platypterus*), and the Swainson (*B. swainsoni*); the rough-legged hawks (*Archibuteo*), two species; and, to a less extent, the marsh harrier (*Circus hudsonius*), and a few other species.

The writer has several times found the remains of rats about the nest of the red-tailed hawk. Of the 562 stomachs of this species examined by Dr. A. K. Fisher, of the Biological Survey, less than 10 per cent contained poultry or game, while more than 70 per cent contained injurious rodents.[a] Most of the other species of buzzard hawks made a better showing even than this, especially the Swainson hawk, which had fed entirely on harmful rodents and insects. The stomachs of rough-legged hawks examined nearly all contained harmful rodents and none of them contained remains of birds of any sort.

A few months ago, while walking on the Potomac flats near Washington, the writer met some boys who had just shot a red-tailed hawk. Its crop was greatly distended, and later examination showed that the bird had recently eaten an enormous brown rat. Although the the shooting was contrary to law, when it was reported to the nearest policeman, his comment was, "Oh, a hawk! Why, it's a good thing to shoot a hawk." The incident illustrates the general popular prejudice against all hawks.

OWLS.

Because they hunt by twilight and at night, owls are more efficient than hawks in destroying rats. All American owls, except the more diminutive species, prey on the common rat. Even the little screech owl (*Otus asio*) feeds on young rats.

Of all our species, the barn owl (*Aluco pratincola*) is preeminent as a destroyer of rats. It lives commonly about farm buildings, sometimes even making its nest and rearing its young in the pigeon loft without molesting the pigeons. In such surroundings its opportunities for securing rats are excellent, and no other wild bird is so useful on the farm. The late Henry Newman once stated that every barn owl is worth £5 a year to the British nation, and the value of the bird to the American farmer is not less.

Owls, hawks, and other birds of prey that swallow their quarry whole or in large pieces do not digest the bones, fur, and feathers. They eject these indigestible parts in the form of large pellets, in which the fur or feathers surround the bones. The contents of these casts

---

[a] Hawks and Owls of the United States, p. 62, 1893.

are an excellent index of the food of owls. Dr. A. K. Fisher, of the Biological Survey, has examined 987 pellets of a pair of barn owls that live in a tower of the Smithsonian building in Washington, and in them found the skulls of no fewer than 192 rats (*Mus norvegicus*), together with those of 554 common mice and 1,508 field mice (*Microtus pennsylvanicus*).

Dr. John I. Northrop found a nest of the barn owl on Andros Island, Bahamas. It contained two young owls and the remains of a black rat (*Mus rattus*). The ground about the nest was covered with pellets which contained remains of the black rat and no other species.[a]

The great horned owl (*Bubo virginianus*) is the largest of our resident owls. It feeds mainly on rodents, though occasionally it takes a fowl found roosting in an exposed situation, as on a fence or in a tree. While it occasionally destroys game birds, the rats it captures would probably destroy ten times as much game as the owl. Charles Dury, of Ohio, in 1886 published a letter from O. E. Niles in which it was stated that he counted 113 dead rats at one time under a nest of this bird.[b]

The snowy owl (*Nyctea nyctea*) is a rather rare winter visitor in the northern United States. It usually arrives when the ground is covered with snow and ordinary food is scarce. Near barns, outbuildings, and stacks it finds its chief subsistence in the common rat; and, if undisturbed, will stay for several weeks in the same locality, destroying many of the pests. Unfortunately, mounted specimens of this beautiful owl are so much in demand that the majority of them fall a prey to the specimen hunter and the taxidermist. The destruction of this bird should be prohibited under heavy penalties.

The barred owl (*Strix varia*), the long-eared owl (*Asio wilsonianus*), and the short-eared owl (*Asio flammeus*) all destroy some rats; but as they do not generally nest or live in the vicinity of farm buildings, the rodents they capture are taken chiefly from the fields. Occasionally a short-eared or a long-eared owl makes its winter home in a group of evergreens near the farm buildings, and does excellent service in clearing the premises of rats and mice. Evergreens are desirable about a country place, if for no other reason than that they attract owls.

The practice of indiscriminately destroying hawks and owls should be discouraged. Game preservers especially should realize that the birds of prey they kill would, if allowed to live, destroy rats, which in the course of a year do many times as much harm to game as the supposed offenders do. Besides, the birds would destroy also large numbers of mice and injurious insects.

---

[a] The Auk, vol. 8, p. 75, 1891.

[b] Jour. Cincinnati Soc. Nat. Hist., vol. 8, p. 63, 1886.

13429—10——12

The farmer and the poultry grower may easily learn to recognize the few harmful species of hawks, and should confine their warfare to these. The practice of setting pole traps for hawks and owls is exceedingly reprehensible, as it results chiefly in the destruction of our beneficial owls when they come about the premises at night in search of rats. Furthermore, the beneficial hawks and owls should have legal protection. The larger hawks, nearly all of which are beneficial, are slow of wing and much more likely to be shot than the swifter and more harmful falcons.

NATIVE WILD MAMMALS.

Not many species of wild carnivorous mammals live where the common rat is abundant. Coyotes, foxes, and a few others occasionally find a rat in the fields, but for the most part they depend for food on native wild rodents and other animals. Chief among the mammals that do good work in destroying rats are skunks, minks, and weasels.

SKUNKS.

Skunks are excellent ratters, and when they take up their abode on the premises of the farmer, they speedily destroy or drive away all rats and mice. This statement applies equally to the large skunks (*Mephitis*) and the little spotted skunks (*Spilogale*). Unfortunately, skunks are seldom allowed to tenant the premises without being molested by either dogs or men. When undisturbed, they are inoffensive, and will stay about the farm buildings or stacks until rats and mice are no longer to be had for food.

Skunks usually hunt by night, and hence poultry properly housed is safe from them. The larger skunks do not climb, and can capture only fowls that roost on the ground. Indeed, so few skunks ever learn to kill poultry that there is no good reason for warfare on the skunk family. Besides destroying mice and rats, the animals are invaluable as consumers of noxious insects, especially cutworms, army worms, white grubs, May beetles, grasshoppers, crickets, and sphinx moths.

WEASELS.

Weasels are good ratters and mousers. Several of our species come about buildings, and often perform excellent service in destroying rats and mice. They are more likely than the skunk to attack poultry, for they can enter the poultry house through smaller openings. At times weasels seem to kill for the mere love of killing, and while occasionally this trait makes them formidable in the poultry house, it also renders them more efficient as destroyers of rodents. A small weasel can follow a rat into all its retreats, and will soon clear a stackyard or shed of all rodents.

Our largest weasel, the black-footed ferret (*Putorius nigripes*), occasionally deserts its wild haunts on the plains and comes about buildings in search of rats and mice. In 1905, while the writer was at Hays, Kans., one of these ferrets took up its quarters under a board sidewalk in the business part of the village. The squealing of the rats it killed was often heard.

As regards the destruction of poultry by weasels, the same care necessary to exclude the rat from a poultry house will keep out the weasel also. When so excluded, a weasel will do no harm about the premises, but may be depended upon to drive out or kill all the rats and mice.

MINKS.

Minks are excellent ratters, but as enemies of poultry are worse than weasels. They destroy fish also. The great demand for mink fur causes close trapping of these animals, and in the future they are not likely to influence greatly the numbers of rodent pests.

DOMESTIC ANIMALS.

Among the enemies of rodents often employed as aids to rat destruction are the dog, cat, and ferret.

DOGS.

The value of dogs as ratters can not be appreciated by those who have had no experience with trained animals. The ordinary cur and the larger breeds of dogs seldom make useful ratters. Small Irish, Scotch, and fox terriers, when well trained, are superior to most other breeds as ratters, and under favorable circumstances may be depended on to keep premises free from rodents. Much, too, may be done by the farmer or householder to increase the effectiveness of his dogs by removing obstructions to their work. Corncribs and outbuildings, when of wood, should not have floors close to the ground, but should have ample room below to permit dogs to move about freely.

With a little preliminary training, most terriers learn to hunt rats independently, and they thus become doubly useful on farms and in warehouses.

CATS.

When the black rat was the dominant species in Europe and America, cats were the chief dependence of the householder against rats; but comparatively few cats will venture to capture a full-grown brown rat. Then, too, the ordinary house cat is too well fed and consequently too lazy to be an efficient ratter.

Occasionally, however, one meets with rat-killing cats whose work in destroying the brown rat has decided value. These cats are rarely of the fine breeds, but generally of the common "tabby" variety, kept in barns or warehouses, fed on milk, and left to forage for their own meat. Managed in this way, cats are far less objectionable on sanitary grounds than when kept in the house as pets. In the country, on the other hand, barn cats are far more likely than the house-kept ones to run at large and prey upon birds and young poultry. Aside from the rat itself, we have no more serious enemy of birds and game than half-wild cats, many of which have been abandoned in fields and woods by the thoughtless. All things considered, cats do not rank high as destroyers of the common brown rat.

FERRETS.

Tame ferrets, like weasels, are inveterate foes of rats, and can follow them into their retreats. Under favorable circumstances ferrets are useful aids to the rat catcher, but their value is often greatly overestimated. They require experienced handling and the additional services of a well-trained dog or two to do effective work. Dogs and ferrets must be thoroughly accustomed to each other. A noisy or excitable dog is useless in ferreting. The ferret should be used only to drive out the rats, which are then killed by the dogs. If an unmuzzled ferret is sent into rat retreats under floors, it is apt to lie up after killing a rat and sucking its blood. Sometimes the ferret will remain for hours in a rat burrow or escape by unguarded exits and be lost.

Such experiences often discourage the amateur ferreter. Besides, ferrets are subject to diseases and require the greatest of care as to their food. For these reasons the use of ferrets to destroy rats, except in the hands of the experienced, is generally expensive and disappointing.

OTHER ANIMALS.

MONGOOSE.

The various species of mongoose (*Herpestes* and *Mongos*) are destroyers of rats, and their importation into this country has often been urged. Many years ago they were introduced into Jamaica and Hawaii to save the sugar plantations from ravages by rats. The mongoose has, however, proved very destructive to native birds and poultry in the islands, and its introduction is now generally regretted. Its importation into the United States is prohibited by law.

ALLIGATORS.

In the South the alligator is said to destroy many rats along levees and banks of streams, and its protection has been urged on this account.

SNAKES.

Our larger snakes are beneficial in destroying rats, mice, prairie squirrels, and pocket gophers. As most of the food of snakes is obtained remote from human abodes, only a small percentage consists of rats.

BOUNTIES ON PREDATORY ANIMALS.

Whatever may be said in favor of bounties on the larger beasts of prey, those on hawks, owls, and the smaller fur-bearing animals can not be justified. Payments of this sort should cease, and laws should be enacted to protect species which careful investigations have shown to be mainly beneficial.

A few States still pay bounties for the destruction of foxes, weasels, skunks, minks, and raccoons. All of these, except the southern weasels, have valuable fur, and hence should be protected as a source of wealth. In addition they do far more good by destroying rats, mice, and other field pests than harm to game and poultry.

The payment of bounties on hawks of any kind is open to the objection that officials hardly ever discriminate between the harmful and the useful kinds, even when the statutes do so. Since the beneficial kinds are the more easily captured, public money is often paid out to reward what really injures the community. The bounty on owls is still more reprehensible, since owls are a more decided check to rodent increase.

The natural enemies of the rat exercise a steady, cumulative effect in restricting the numbers of the pest. That the effect is not greater is largely our own fault, since instead of protecting the birds and mammals that prey on the rat, we destroy them, sometimes even offering bounties on their heads. In future our aim should be to increase their numbers and to protect them in every way possible.

RAT PROOFING AS AN ANTIPLAGUE MEASURE.

By Richard H. Creel,
Passed Assistant Surgeon, United States Public Health and Marine-Hospital Service.

To appreciate the great importance and absolute necessity of rat proofing as an antiplague measure, it is only necessary to consider the results that have followed its use as compared with other measures that have been relied on in recent years in combating this disease. These were, briefly, disinfection, evacuation, or destruction of buildings in infected areas, preventive inoculations, and destruction of rats either by poison or by trapping.

Plague was formerly believed to be communicable by aerial transmission and through the agency of fomites. Sanitarians have, therefore, put great faith in disinfection procedures, but the results have never been satisfactory, and it is only necessary to consider the method of transmission of plague to perceive the fatuity of bactericidal measures. Measures intended for the destruction of fleas are also of relatively small value. It is well worth while to destroy all fleas possible, but if those infesting the rat population escape, the efforts will have had little effect in preventing the spread of plague. It is only those fleas that infest rats and their habitats that are of importance in relation to the transmission of disease, and it is only by rat proofing that their destruction in rat burrows and runs can be accomplished.

Rat-proofing of individual buildings is of no recent date, but new emphasis was laid on rat-proofing as a separate and distinct antiplague measure by Passed Assistant Surgeon Mark J. White in an article written in the fall of 1907.[a]

Disinfecting procedures must be regarded as of minor importance in plague prevention, except in pneumonic cases where its use is imperative. It is not intended to depreciate the value of disinfection, but rather to estimate its exact value as an antipest measure. Time and money should not be wasted nor a feeling of false security engendered by using an ineffective measure when others, as rat proof-

[a] Journal American Medical Association October 19, 1907.

ing, of much greater value are at hand. As an example of this might be cited an outbreak of plague in one of the refugee camps during the recent epidemic of the disease in San Francisco. This camp covered several blocks and housed between two and three thousand people. The camp grounds throughout and the houses were disinfected and disinfected well. At the same time, every effort was made to poison and trap rats. Notwithstanding these precautions, cases continued to occur, but when the houses were elevated there followed an immediate cessation of plague cases in the camp.

Another case of infected premises proved equally refractory to disinfection. The place was a large two-story frame dwelling located in the center of the city and in a good neighborhood. The yard was planked, as was also a part of the basement, the latter being used as a storeroom. On November 1 there occurred in this dwelling a fatal case of human plague, and plague rats were found at the same time. The place was disinfected in the usual manner and thorough measures were taken to trap and poison rats with apparent subsidence of infection, but on January 22 a plague rat was trapped, followed by another on January 31, after which the occupant of the building vacated it in great alarm. All planking was then removed from the yard and basement and concrete substituted by the owner, the place thereby being rendered thoroughly rat proof, and no plague rats were subsequently taken from that dwelling or in its immediate neighborhood.

In 1902 the plague outbreak was almost wholly confined to the Chinese colony. Chinatown was made the battle ground, and among other measures rat proofing was enforced, with the result that after the fire it was by far the most sanitary district in the city of San Francisco from a structural point of view. The buildings when erected were made rat proof from cellar to garret. The Chinese had had their lesson, and to their credit it must be stated that they responded with a greater show of intelligence than did some of the residents in surrounding districts.

Adjacent to the Chinese colony is the Latin quarter. In the rebuilding of this section, no attention was paid to rat proofing; consequently many of the buildings consisted of small shacks set on the ground or abutting some insanitary stable, and were therefore ideal rat harbors. On account of these conditions the natural results followed. Chinatown, on the other hand, which had contributed in the previous epidemic almost the entire number of plague cases during the epidemic of 1907, did not furnish more than two or three of the plague cases reported; that is, less than 2 per cent of the total cases reported, while the Italian colony, including North Beach district, probably furnished over 50 per cent of the total.

The evacuation or burning of buildings can hardly be called a successful measure any more than a retreat can be styled a victory; moreover, there can be no question from an economic standpoint as to the value of rat proofing over abandonment except in a few isolated cases of dilapidated insanitary property.

Schemes and plans for demurization, total or partial, have been as numerous and varied as they have been unsuccessful. Traps and poisons have been the agencies of destruction, but until some highly communicable epizootic peculiar to rodents shall have been discovered, absolute eradication of the rat can be considered as nothing less than impossible.

A recognized authority on plague, Major Morehead, of the Indian Medical Service, states that "rat destruction is of doubtful value," referring, of course, to trapping and poisoning when those measures are used solely without auxiliary measures. He agrees with Japanese authorities in their arguments that as rat populations decrease, the breeding rate among survivors increases, due, obviously, in part at least, to increased food supply and harboring facilities. Such a result is assured where rat proofing is not accomplished at the same time. This latter procedure, by destroying rat harborages and cutting off food supplies bring about conditions unfavorable to breeding.

The total eradication of rats in a locality is not absolutely necessary, however, to the eradication of plague. If the rat population is kept within fairly low limits, rat centers destroyed, and such rat population as does exist well scattered and not congested, it is ventured that rat plague will disappear from a locality. Plague among rats in San Francisco ceased to appear when the number of rodents was reduced some 50 per cent, but such reduction was accomplished only after six months of ceaseless endeavor, which included also the rat proofing of the bakeries, stables, and markets in the city.

It is a logical supposition that close contact is just as essential for the propagation of plague among rats as it is for the spread of certain communicable diseases among human beings, the increase of cases being in direct proportion to the density of population and closeness of contact.

RAT PROOFING OF PRIMARY IMPORTANCE.

Without the general enforcement of rat proofing antiplague measures are bound to be more or less temporary and decidedly unsatisfactory. This subject is of immense importance to the public, both from a sanitary and a commercial standpoint, but the latter aspect of the question is more apt to prove of interest to most communities.

The measures necessary to render buildings rat proof are the same, however, whether they be instituted for sanitary or for commercial reasons. Rat proofing will, therefore, be considered entirely from a sanitary standpoint; but it can be understood that granaries, bakeries, butcher shops, packing houses, dwellings, and other places, if rat proofed for sanitary reasons, are just as much protected from depredation of the rat as though the work had been performed for commercial reasons alone.

Rat proofing has a twofold objective. It serves as a protection to the inmates of a building, and excludes rodents from sources of food supplies and harboring places. While rat proofing should be enforced as a general measure in all plague-infected localities, it is imperatively demanded in premises whereon have occurred cases of human or rodent plague.

Plague-infected localities or places that contain food must be rendered impervious to rats in order to insure the success of other preventive measures. Rats can be trapped or poisoned only when other food supply is excluded. A rat will enter a trap for food or will eat poisoned preparations not because of their greater attractiveness, but because of their greater availability. It therefore follows that rat proofing of food supplies is a prerequisite to success in rat eradication. The food depots requiring attention in the order of importance are stables, meat markets, bakeries, restaurants, groceries, warehouses, and private dwellings.

It is logical to suppose that the most common mode of infection is by reason of plague rats dying in the walls, roofs, or floorings of human habitations. As soon as the rat's body is cold the fleas abandon it for another rat, some domestic animal, or human being. The risk to human inmates in such infected houses, therefore, is evident.

That rat proofing is a valuable measure is shown by the reports of the British Plague Commission where are mentioned the results following the use of rat-proof "go-downs" and those not so constructed. Additional evidence is presented by the fact that appalling epidemics of plague have ravaged India and the China coast, whereas in the Philippine Islands but few people die of the disease. It would appear that the comparatively few cases in the Philippine Islands were due to the fact that most Philippine dwellings are rat proof by reason of being elevated from the ground and the fact that the walls are thin and offer no refuge whatever to rats.

RAT PROOFING IS EXPENSIVE.

The almost insuperable obstacle that will usually confront the sanitary authorities in such work will be either the financial inability of the unfortunate community or the sordid unwillingness to make any expenditure that does not promise personal gain.

When the influence of the mosquito in the transmission of yellow fever was proven, recourse was had to mosquito proofing of both the sick and the well as a preventive measure. Rat proofing in plague is just as rational and necessary, but the financial expenditure contemplated thereby has been of such proportion as to cause the majority of sanitary authorities in different parts of the world to dismiss the idea as impossible.

To properly rat proof a city undeniably requires enormous expenditures, but no antiplague campaign was ever waged without an immense outlay of both money and labor. If allowed to progress unchecked, however, plague, either through ravages of the population or through commercial interference, is ruinous. To fight plague, therefore, is the only alternative, and a costly campaign should be anticipated and prepared for in advance. To merely put out traps and poisons without the preliminary rat proofing required can be productive of little good and no permanency. Such a plan of campaign may be attractive because of its relative cheapness, but any city or country that relies wholly on such measures is practicing false economy and deferring the day of reckoning.

It becomes evident, therefore, that rat proofing is of the greatest value as an antiplague measure, and that practical results to be expected are much greater than with any other method.

As has already been stated, the individual premises on which plague either among rodents or human beings has occurred demand first and immediate attention. The work should be extended as rapidly as possible from the point of infection so as to include the entire block and neighboring blocks.

While the chief energies should be centered on plague-infected foci, similar work should be carried on simultaneously throughout the city.

METHODS OF RAT PROOFING.

If plague occurs in the grounds of dwellings the following course should be pursued: All planked-over areas, including sidewalks, that might possibly shelter a rat should be removed, leaving either bare ground or, at the option of the owner, gravel or concrete used, the gravel being preferable. Small sheds should be elevated, or their ground floors concreted. Wood sheds should probably be left without flooring, wood kindling or other contents being piled on elevated platforms provided for the purpose. Stables on the premises should be treated as indicated in a subsequent paragraph relating to these structures.

The garbage depository must be given most careful attention. It should be a metal receptacle, preferably a galvanized can, water-tight to prevent seepage which would attract rats, and there should be a closely fitting lid. A can 2 feet in height without cover will not be proof against the incursion of rats.

The rat proofing of chicken yards is a difficult task as most chickens in private families are fed on table scraps, thereby attracting and supporting a fair quota of rats. The entire inclosure should be protected by wire fencing 6 feet high and of a mesh not larger than a half inch. Ordinary poultry netting is inadequate, the mesh being too large. The edge of the yard should be of concrete construction, the concrete extending 1 foot upward and 2 feet inward. If, on any subsequent inspection, rats have been found to have burrowed into the inclosure, the entire area should be concreted, sand or earth being allowed as a top dressing.

It would seem sufficient to confine these specifications to a feeding pen, but in practice this will not suffice, as a mere pretext of such a place would be built, and the housewife would continue to throw scraps into the unprotected yard.

The dwelling house itself should receive the most careful attention. If it is a small frame structure the cheapest and most effective means of rendering it free from rats is by elevating it, the minimum height being 1½ feet, measured from the most dependent joist. At the same time, all underpinning should be freed of rubbish or other material. It is not sufficient to raise the structure a few inches so as to permit the entrance of cats and other enemies of the rat. Such height and exposure must be secured as to deprive all rodents of cover.

If the house is of more substantial structure, and always if it has a cellar or basement, concrete or some other rat-proof material should be adopted. If sound foundation walls of stone or brick exist, then only the addition of a concrete floor is necessary. The stopping up of rat holes in any substance pervious to rats is at best a poor expedient.

The grounds must be rendered rat proof by piling all loose materials at such an elevation as will preclude rat harborage. All rubbish should be burned or otherwise destroyed. All basement windows should be properly protected against the ingress of rats, and if the *Mus rattus* be present, even second and third story windows should not be considered too high to afford them entrance.

All loose materials on the premises should be properly piled, even though they are in a rat-proof cellar. It is not probable that the *Mus decumanus* would remain or breed in any place where it could not burrow; but no encouragement should be offered to any rodent let in by carelessly left open doors. There have been cases where the black rat has lived, increased, and overrun a house which was structurally rat proof, but in which there was allowed easy access through open windows and doors, and great piles of loose materials and dunnage furnish harborage.

Stables are of two-fold importance because they provide a source of food supply for rats and furnish harborage. All grain must be kept in a metal-lined box or granary. A small stable is sufficiently rat proof if it has an elevation of 2 feet with clear underpinning, provided the floor is rendered impervious to falling grain. Barns of larger extent are best made rat proof by concrete flooring tight on the ground, and the area walls should be of concrete 1 foot high or of galvanized iron of standard thickness. The ingredients of concrete should be specified as to quality and quantity.

The windows of stables should be screened, especially if black rats be present. To render a large livery stable rat proof, however, is hardly practicable, owing to doors being open almost continuously, but rat proofing even in such buildings will destroy rat harborage and limit rat invasions to an occasional migratory rodent. With concrete flooring and protected feed pens it should be an easy task to keep such a building free from rats.

Finally, manure pens should be rat proof or the manure thrown into the corner of the rat-proof stable, provided there is frequent cartage.

RAT-PROOFING ORDINANCES SHOULD BE SPECIFIC.

Any law or ordinance providing for rat proofing should specifically state the minimum thickness of concrete and cement. Concrete 4 inches deep with one-half inch dressing of cement or 1-inch asphalt answers very well. Area walls if of concrete should be 6 inches thick, and the floors should have sufficient slant to allow drainage.

Any expedient as galvanized iron sunk into the ground and made flush with the flooring will not prove of practical value, as it allows rat-harboring space to exist beneath the flooring, and sooner or later rats will gain access thereto by burrowing under the iron gratings or through the wooden flooring.

Meat markets should have concrete floors with cement or asphalt dressing, the floors to be close on the ground and surrounded by properly constructed foundation walls of stone or brick in cement. Water-tight metal cans should be provided for all scraps, and especially for the sawdust with its admixture of fine pieces of meat.

Bakeries and restaurant kitchens should be treated in the same way as meat markets. Packing houses, slaughter pens, warehouses, and food depots in general should be concreted.

The water front demands the greatest attention. The piers and wharves should be of concrete or steel construction. The shipping should be shored off from the dock, and all lines properly rat guarded. When not in use, gang planks should be lifted. Notwithstanding these precautions, rats will be imported from time to time, and the only practical way to prevent their getting ashore will be the sytematic and routine fumigation of ships by the quarantine authorities.

The rat proofing of sewers is open to argument. Of all places in a city the sewer is certainly the one where rats can die with the least danger to the human population. For this reason the sewer should be the last structure in a municipality to be made rat proof. The movements and migrations of rats should be controlled to the extent of making corner catch basins their sole means of entrance and exit to sewers. The small and large iron-pipe mains require no attention in this respect, but where mains are constructed of brick, and especially where they are old and in bad repair, they should be repaired, all rat runs leading from the sewer walls being stopped up and all blind sewers being closed. By this means there will be prevented the breeding of rats in these areas.

The rat proofing of catch basins by any method that would not also block the entrance to the basin seems hardly possible. Properly trapped basins, however, will be found almost as effective and just as desirable.

To attain efficient rat proofing requires necessary laws or ordinances and public sentiment favoring their enforcement. Dead-letter laws that form no small part of many city statutes attest the fact that favorable public opinion is almost indispensable to their enforcement. However, well-drafted laws, clear and specific in requirement and impartially and consistently enforced, inevitably lessen and destroy opposition.

In the foregoing are contained general principles necessary to rat proofing in the case of an outbreak of plague. Due allowance will have to be made, however, for local conditions, and special considerations as they arise, as no unvarying plan will be practical of application in every instance.

CHOICE OF ARCHITECTURE AND BUILDING MATERIALS.

Cities and countries have from time to time wholly revolutionized their type of buildings and constructive materials for either commercial or æsthetic reasons. It is suggested that ports having trade relations with countries where plague prevails should bear in mind the advisability of taking advantage of this fact and revise their building laws with the view to rendering all new buildings rat proof.

Concrete has been advocated for purposes of rat proofing because of its durability and relative cheapness. Concrete flooring or side walls can be made more durable, however, by embedding therein steel netting of 1 or 2 inch mesh. By this method the cost of construction will probably be reduced, as a thinner layer of concrete would be sufficient, and the metal would be protected, thereby adding stability. Such construction at the same time would be doubly rat proof.

THE INEFFICIENCY OF BACTERIAL VIRUSES IN THE EXTERMINATION OF RATS.

By M. J. Rosenau,

Surgeon, U. S. Public Health and Marine-Hospital Service, Washington, D. C., now Professor of Preventive Medicine, Harvard University Medical School.

INTRODUCTION.

Rats are notoriously resistant to bacterial infections. About the only exception is the plague bacillus. Plague among rats occurs both in endemic and epidemic form. When we recall that this virulent disease, which spreads readily from rat to rat, neither eradicates these rodents nor, as a rule, makes any appreciable inroads on the number of rats, we can hardly expect that an artificially induced bacterial disease would be successful. No other known bacterial infection has such a virulence for rats as the plague bacillus has maintained. Epizootics of bacterial nature, therefore, can not be classed among the natural enemies of the rat. Despite this fact persistent efforts have been made to create artificial epizootics to combat these dangerous and destructive rodents, but with little success.

The bacterial viruses that have been used for the destruction of rats and mice belong to the colon-typhoid group[a] and excite enteritis of different characters and a septicemia.

In 1889 Loeffler discovered and described a bacillus which he called the bacillus of mouse typhoid (*B. typhi murium*). He isolated this organism from a spontaneous epidemic which occurred among white mice in the Hygienic Institute at Griefswald.[b] He determined that this bacillus not only caused the death of his mice in the laboratory, but also that the infection was taken into the system of the mouse by ingestion. He found the cultures to be especially virulent for field mice (*Arvicola arvalis*). Loeffler gives a complete description

---

[a] More particularly the hog-cholera group, which includes the para-typhoid organisms.

[b] Loeffler, F.: Ueber Epidemieen unter den im hygienischen Institute zu Griefswald gehalten Mäusen und über die Bekämpfung der Feldmausplage. Centblt. f. Bakt., Orig., vol. 11, 1892, pp. 129–141.

of the bacillus which, from a biologic standpoint, is the parent stock of almost all subsequent work along this line. The bacillus used by Danysz and other workers is either identical with or very closely allied to Loeffler's bacillus of mouse typhoid.

In 1892 Loeffler[a] personally undertook a campaign against the field mice in Thessaly and reported satisfactory results. The depredations carried on by the mice were checked within eight to nine days.

The English commission[b] threw doubt upon the Thessaly operations and concluded that the bacillus as a means of destruction of mice has no value. They found the method to be expensive, affecting only one species of mice; further, that the epidemic-like spread of the disease in the fields was not sufficiently investigated, and that the infected material retains its virulence only for eight days and does not permit of being used in continued bad weather.

Loeffler's optimistic report, however, stimulated many similar trials with varying success. Practically all these efforts were directed against mice, until 1900, when Danysz took up the subject from the standpoint of the rat and plague.

Danysz found that Loeffler's *Bacillus typhi murium* proved to be pathogenic for ordinary mice (*Mus musculus*) and for field or harvest mice (*Mus arvicolis*), but not for rats.

The culture isolated by Laser[c] in 1892 was pathogenic for field mice (*Mus agrarius*); this organism killed 70 of the 76 mice which were used as experiment animals at the Hygienic Institute at Königsberg.

Mereschkowsky[d] in June, 1893, isolated an organism belonging to this group from a ground squirrel known as the Zisel (*Spermophilus musicus*). This culture killed domestic and field mice when placed in their food, but was not pathogenic for rats.

The Japanese investigator Issatchenko,[e] in 1898, briefly described a bacillus obtained by him from gray [white?] rats, which proved virulent for rats and mice.

Each of these various bacilli is of such variable virulence that it could not be used for the destruction of all species of these rodents.

---

[a] Loeffler, F.: Die Feldmausplage in Thessalien und ihre erfolgreiche Bekämpfung mittels des *Bacillus typhi murium*. Centblt. f. Bakt., Orig., vol. 12, 1892, p. 1.

[b] Wien. landw. Zeit. 1894, p. 783.

[c] Laser, Hugo: Ein neuer für Versuchsthiere pathogener Bacillus aus der Gruppe der Frettschen-Schweinseuche. Centblt. f. Bakt., Orig., vol. 11, 1892, p. 184.

[d] Mereschkowsky, S. S.: Ein aus Zieselmäusen ausgeschiedener und zur Vertilgung von Feld-resp. Hausmäusen geeigneter Bacillus. Centblt. f. Bakt., Orig., vol. 17, 1895, p. 742.

[e] Issatchenko, B.: Untersuchungen mit dem für Ratten pathogenen Bacillus. Centblt. f. Bakt., Orig., vol. 31, 1902, p. 26.

Danysz[a] therefore conceived the notion that it would be of great interest first to extend the field of action of one of these organisms by increasing its virulence so that it would attack other species of rodents, and then maintain this increased virulence at its highest point.

In 1900 Danysz isolated a bacillus from a spontaneous epidemic among harvest mice. This organism was a cocco-bacillus presenting the general characteristics of the colon-typhoid group and resembling the bacillus of Loeffler—*B. typhi murium.* From the first this bacillus showed a slight pathogenicity for gray rats (*M. decumanus*). Out of 10 animals fed with a culture of this microbe 2 or 3 would die; several others would sicken and recover; others appeared completely refractory. The fact that a certain number of the rats fed with these cultures always succumbed led to the hope that it would be possible to increase the virulence of this particular microbe by the generally accepted methods—that is to say, by a certain number of passages from rat to rat.

Danysz first tried to increase the virulence of the organism by this means, but he found that successive passages from rat to rat, whether by feeding or by subcutaneous injection, ended by enfeebling rather than increasing the virulence of the microbe. He found that it was rarely possible to go beyond 10 to 12 passages. Sometimes the series was stopped at the fifth passage, or even sooner, by the survival of all the animals undergoing experiment. The result was exactly the same if, instead of alternating each passage through the animal by a culture in bouillon or agar, the bodies of animals dead of a preceding passage were fed to others.

It was therefore plain that in the evolution of an epidemic caused by this microbe it was necessary to take account of the indisputable diminution of the virulence of the microbe, as well as the natural resistance of the survivors.

Passage of cultures in collodion sacs inclosed in the peritoneal cavities of rats was tried, both in interrupted series and by alternating each sac culture with a culture in bouillon or on agar, but the end was invariably a notable diminution of virulence when administered by the digestive tract.

Finally, after long and painstaking procedures, Danysz obtained a very virulent culture that, contained in flasks and kept from the influence of light and air, preserved its virulence for several months. Planted on agar it preserved its virulence without appreciable diminution for two months under laboratory conditions. In bouillon, in flasks, or in tubes stoppered with cotton it altered very rapidly.

---

[a] Danysz, J.: Un microbe pathogène pour les rats (*Mus decumanus* et *Mus rattus*) et son application à la destruction de ces animaux. Ann. Inst. Pasteur, vol. 14, 1900, p. 193.

13429—10——13

DESCRIPTION OF THE ORGANISM.

A culture of Danysz's virus obtained from the Pasteur Institute had the following characteristics:

The organism is a cocco-bacillus showing distinct motility. Stains well by the ordinary stains, but does not stain by Gram's method.

It grows well at ordinary room temperature, also in the incubator, and on all the ordinary media. In bouillon it produces a uniform cloudiness in twenty-four hours. A slight scum forms after several days' growth, which falls to the bottom when shaken. In Dunham's solution it grows well, but produces no indol in twenty-four hours' growth.

It does not coagulate milk.

It grows the whole length of the stab in gelatin, forming small whitish colonies in the deeper portions of the tube. It does not grow over the entire surface of the gelatin tube; does not liquefy gelatin.

It grows under anærobic conditions.

It ferments glucose bouillon, but not lactose bouillon. In glucose bouillon it produces 1–CO_2, 5–H. It also produces H_2S.

From a general biological standpoint it is plain that this bacillus belongs to the para-typhoid group, and is very similar to the bacillus of hog cholera as well as the *Bacillus icteroides*, also *B. enteritidis*, so far as its morphological and cultural characteristics are concerned.

In the following table the fermentations produced by various members of this group upon certain carbohydrates are shown:

Organism.	Lactose.	Saccharose.	Maltose.	Mannete.	Glucose.	Levulose.
B. typhosus	–	–	–	–	–	–
B. dysenteriæ Shiga	–	–	–	–	–	(a)
B. dysenteriæ Kruse	–	–	–	–	–	(a)
B. para-typhosus A	–	–	+	+	+	+
B. para-typhosus B	–	–	+	+	+	+
B. para colon	–	–	+	+	+	+
B. acidi lactici	+	–	+	+	+	+
B. hog cholera	–	–	+	+	+	+
B. typhi murium Danysz	–	–	+	+	+	+
B. icteroides	–	–	+	+	+	+
B. enteritidis	–	–	+	+	+	+
B. coli communis	+	+	+	+	+	+

a Or bubble.

EXPERIMENTS UPON RAT VIRUS IN THE HYGIENIC LABORATORY.

In 1901 I made an investigation of this pathogenic microbe (*B. typhi murium*) applied to the destruction of rats under laboratory conditions.[a] One hundred and fifteen rats were fed with the cultures in various ways during the course of these experiments with the virus. Of these, 46 died—less than half.

Most of the rats used were the gray rat (*M. decumanus* or *norvegicus*) and the tame white rat. A few (8) of the wild black or house rats (*M. rattus*) were used.

The virus is in reality pathogenic for these three kinds of rats when ingested. No special difference was noted in its effects upon the various species.

As the work progressed it soon became evident to me that the result depended largely upon the amount of the culture ingested. By starving rats for a day or two and then giving them all they could be induced to eat and drink of the cultures, a very positive result was obtained. In one instance of 27 rats so fed all died within a week. If the rats are given a small amount the effect is uncertain—only a few die. In one instance I fed 70 rats with 4 agar tubes and only 7 died. Feeding them a second time with very large quantities 9 more died. The survivors were then fed with all they could be induced to eat every day for a week without effect.

It seems plain, therefore, that a large primary dose proves fatal, and a small dose is not only uncertain, but produces an immunity. This is a very important factor, for it is likely that in the wild state rats would often partake of an amount too small to cause death. Such rats may then subsequently eat large amounts of the culture with impunity.

It would seem then that, after all, the virus is not so different from the laying of a chemical poison, depending as it does for its effect upon the amount ingested. A chemical poison, however, does not possess the disadvantage of producing an immunity. Another disadvantage possessed by the virus is the rapid deterioration in virulence which occurs when it is exposed to the action of air and light, or when it becomes dry, as is very apt to happen when laid out for rats in the wild state.

Since these early experiments, tests have been made of various rat viruses in the Hygienic Laboratory, and the results are given in the following pages:

---

[a] Rosenau, M. J.: An investigation of a pathogenic microbe (*B. typhi murium* Danysz) applied to the destruction of rats. Bull. No. 5 of the Hygienic Laboratory, U. S. Mar. Hosp. Serv., Washington, 1901, 11 p.

AZOA.

Series 1. Single feeding of azoa in oatmeal. Rats starved twenty-four hours before feeding. Three out of eight animals died in four, five, and seven days, respectively. Micro-organisms resembling the predominant one of azoa could not be isolated from their hearts' blood. The organs of these dead rats were fed to fresh rats with the result that one of the three died. It must be mentioned that the mortality among our fresh rats was nearly as high as that in the experimental animals from a disease probably due to infection with an animal parasite.

Series 2. Daily feedings with azoa in oatmeal. Five white rats fed with the mixture, a constant supply being kept in the cage. These animals were picked rats freshly obtained from the dealer. One rat died after seven days. It was heavily infested with lice. The azoa organism could not be found in the blood. The rest remained well after twenty-five days.

Series 3. Black tame mice, daily feedings. One of the five died after seven days. The rest remained well after fourteen days.

These experiments indicate that azoa is not pathogenic for white rats and black tame mice to a degree rendering it applicable for vermin extermination on a practical scale, provided that its action is no more pathogenic for the wild than for the tame species.

RATITE.

The manufacturers recommend a single feeding of this substance rather than a continued exhibition of the virus.

Series 1. Five white rats starved twenty-four hours and then fed with a mixture of ratite and oatmeal. Subsequent daily feedings with plain oatmeal. Picked animals fresh from the dealer. One animal died after twelve days; too much putrefied for further examination; had been heavily infested with lice. The remaining rats are well after twenty-five days.

Series 2. Five black tame mice fed as above. Three were found dead after eighteen days and the other two after nineteen days. Further experiments were not made, as putrefaction was too far advanced when they were found. The room in which they were kept had been unusually cold just before their death owing to a sudden and unexpected drop in the external temperature.

Ratite does not appear to be very pathogenic for white rats. All the five mice fed with ratite died in eighteen to nineteen days (much longer than the advertised incubation period of the infection), but their death could be reasonably attributed to unusual cold. This part of the test is therefore invalidated except that the animals lived considerably longer than would be expected from the literature furnished by the manufacturers, which says that the effects of laying the virus will be apparent in eight to ten days.

DANYSZ VIRUS.

Twelve tubes of Danysz virus were sent to the laboratory for examination April 7 by the Independent Chemical Company, agent for Danysz Virus Company (Limited). The label stated "Keep in a cool place and at above temperature; use before May 15, 1909."

The virus was kept at 15° C. until April 13, when it was turned over to Passed Asst. Surg. W. H. Frost, who made the following tests:

One tube opened. Cultures made on two agar tubes were found to correspond in cultural characteristics with the bacillus of Danysz virus as generally described. The remainder of the tube prepared according to directions in accompanying circular, using stale dry bread 2 ounces and suspension of the culture in normal salt solution.

Series 1. Approximately equal parts, then fed to six white rats in individual cages, they having not been fed for twenty-four hours previously. Rats all ate greater part of infected food.

Five rats of series 1 died within five to seven days and were partly eaten before being removed from the cage. The pathological changes in all cases were chiefly enlargement and congestion of spleen and liver, and in some cases inflammation of small intestine. In each case an organism was obtained, usually in pure culture, from one or more organs, corresponding culturally and morphologically with cultures taken from original tube.

Series 2. April 14: Rats all ate greater part of infected food. Transferred to large cage containing nine other white rats. Nine other white rats exposed to infection by being placed in a large cage with the rats of series 1. Four of the nine rats of this series died in four to seven days after eating infected rats.

Pathological changes and results of cultures from internal organs the same as with series 1. Autopsy and cultures impossible in one case, where body was almost completely devoured.

Series 3. May 5: Three of the six surviving rats (one from series 1, two from series 2) were placed in individual cages, deprived of food for twenty-four hours, then fed each with one-third agar tube cultures of Danysz virus (the same used in the original feeding). All three ate practically all the virus given.

All three of these rats remain alive and well after two months.

Summary.—Series 1. Six rats each fed one-twelfth to one-sixteenth agar culture Danysz virus. Five died within five to seven days.

Series 2. Nine rats exposed to infection by being placed in cage with series 1. Four died within eight to twelve days after death of first rat of series 1.

Series 3. Three of the surviving rats (1 from series 1 and 2 from series 2) fed each with one-third agar tube of original Danysz virus as used in series 1. None died.

TRANSATLANTIC RATIN.

A can of this substance labeled "Transatlantic ratin" was furnished by the American agents representing the Bacteriological Laboratory, Copenhagen, Denmark. The can bore the date January 26, 1909, and was stated to be "effective for six months from date of production."

On April 13, 1909, this sample was given to Passed Asst. Surg. W. H. Frost for examination, and he obtained the following results:

April 13, 1909: Can of ratin opened with aseptic precautions. Contents mixed with about equal bulk of clean fresh lard.

A portion of this about equal to one tablespoonful fed to each of six white rats previously deprived of food for twenty-four hours. All the rats ate some of the bait at once. Feeding at 2 p. m.

April 14: Five rats very sick, having convulsions; partially paralyzed. One dead.

April 15: Three more rats found dead. Remaining 2 recovering.

The pathological change in all the above cases consisted chiefly of intense congestion of intestines, both large and small.

Cultures from the original case of ratin, on agar, bouillon, and in fermentation tubes, negative except staphylococcus in one tube.

Cultures taken from heart's blood and other organs of the 4 dead rats all negative, except in one case a growth of a staphylococcus resembling *S. pyogenes citreus.*

April 20: Two rats fed on half agar slant culture of the staphylococcus obtained from heart's blood of rat No. 1. Result of feeding negative after several weeks.

NOTE. The absence of a colon-like organism in this virus and the rapid death of the animals with convulsions suggested a chemical poison, which it is believed this can contained.—M. J. R.

EXPERIMENTS WITH MICRO-ORGANISMS FOR DESTROYING RATS, CONDUCTED BY THE UNITED STATES BIOLOGICAL SURVEY.[a]

RATIN.

The Biological Survey, Department of Agriculture, in cooperation with the Bureau of Animal Industry, has experimented with "ratin." The material (ratin No. 2—labeled "Transatlantic ratin") was furnished by the American agents in New York. Although the agent claimed that this was a bacterial preparation and that "it would kill

[a] This report was furnished by Dr. A. Hart Merriam, Director of the Biological Survey.

for six generations," it proved to be a glucoside poison (probably squills) and contained no bacteria of any kind. A number of experiments were made with it, and it proved to be an effective rat poison. In some instances the animals died within two hours after eating it, and in two experiments all the animals fed died within twelve hours. In other experiments, however, a considerable percentage of the affected rats recovered, and subsequent attempts to kill them with ratin No. 2 failed. Some were immune to its effects and others too wise to eat it a second time. More than a hundred rats were used in the experiments; but the main object—to test the communicability of the disease caused by ratin bacteria in healthy rats—failed, of course, since, as above stated, the preparation experimented with contained no bacteria, but was merely a vegetable poison. Before its character was fully determined, 15 rats killed in the experiments were eaten by 5 healthy rats; the latter were unaffected.

It should be noted that the labels on the tins containing trans-Atlantic ratin were misleading. The user was warned to open the packages in dim light and to allow no moisture to come in contact with the contents, as the bacteria were very sensitive to light and moisture. The contents of the can were to be used at once. As a matter of fact the contents of one can were exposed to severe drying in heat and sunlight for four days and then soaked in water for two days. Afterwards the preparation was fed to different rats for a further period of four days, and its virulence was retained to the last.

The trans-Atlantic ratin is in a solid medium, apparently bread and molasses. Its keeping qualities are excellent, and it is an effective poison for rats, but far too expensive for extensive use. A can costing $1.50 is enough for only 15 baits.

Its harmfulness to domestic animals was not fully tested. Dogs and cats refused to eat it and vomited it when it was forced upon them. Several animals, including a dog, were killed by injections of the poison in concentrated form.

A shipment of ratin No. 1 (the solid bacterial ratin, said to retain its virulence for two months) was received June 4, 1909. This preparation was dated May 8 and should have been still virulent. The contents of a can mixed with milk was fed to 8 adult rats on June 7. All of the baits were eaten, but no result followed. Cultures of the bacteria showed strong growths of new colonies.

On July 6 the contents of another can were fed to 1 adult and 16 young rats. One of the young was found dead on the morning of July 14. Cultures were made from the dead rat, but the bacillus was not recovered. Up to July 28 none of the other rats have been affected.

AZOA.

Several trials of azoa for the destruction of rats have come under the observation of members of the Biological Survey. Experiments made in the building occupied by the Interstate Commerce Commission were at first promising, but from a second invoice of the virus no results were obtained. In the buildings of the National Zoological Park 72 bottles of azoa were used, but the results were for the most part negative. In a store in south Washington where this preparation had been used the stench of dead rats was very strong, showing a measure of success.

DANYSZ BACILLUS.

Some three years ago the Biological Survey, assisted by the Bureau of Animal Industry, tested the efficiency of Danysz virus. In the laboratory from 10 to 50 per cent of rats fed on the virus died. In the field, however, results obtained were unsatisfactory. Only 1 dead rat was found from which the bacillus was recovered. Experiments with field mice gave better results. All the mice fed in confinement died, and field experiments resulted in many dead mice from which the bacillus was recovered.

EXPERIMENTS DURING THE SAN FRANCISCO PLAGUE OUTBREAK.[a]

Several proprietary biological products sold as rat exterminators were made the subject of seven experiments on wild San Francisco rats, for the purpose of ascertaining whether they were efficient for the purpose for which they were sold. Seventy-six rats were used in these experiments. About 10 per cent died within a month and there was considerable doubt as to whether all of the deaths that occurred were due to the agent used.

The following is a brief statement of the work done with these agents. In each case the rats used were wild *Mus norvegicus*, caught in San Francisco.

RATIN NO. 1.

Made by the Bakteriologik Laboratorium, Copenhagen, marked: "Effective two months from April 28, 1908." The preparation comes ready for use in the form of a moist, mealy mass. On May 28, about 6 ounces of the material was fed to 12 rats. They all remained well until thirty days after feeding them when the experiment was regarded as terminated.

[a] These experiments were made by Passed Asst. Surg. G. W. McCoy, United States Public Health and Marine-Hospital Service, in 1907-8 during the plague campaign in San Francisco and here published for the first time.

DANYSZ VIRUS.

The Danysz Virus Company (Limited), of London, furnished a preparation in the form of a culture on a slant of solid medium, said to be gelatine. The tube was marked: "To be used before June 1, 1908." The contents of the tube, mixed with bread, according to directions, was fed to 6 rats. On the twenty-first day but 4 rats remained, 2 having died and been devoured by their companions. The 4 that remained were chloroformed, as the cage was needed for other purposes. Post-mortem examination showed them to be entirely normal.

RATITE.

Furnished by the Pasteur Vaccine Company, Chicago. This preparation is in the form of a culture in a liquid medium, presumably broth. The bottle was dated April 10, 1908, and the label stated that it should be used within twenty days from date of preparation. On April 29, 1908, 9 rats were fed with about 6 ounces of the preparation, mixed according to directions. The rats all remained alive and well, and when chloroformed on June 1, 1908, presented no abnormality on post-mortem examination. In another experiment the contents of a bottle of ratite was fed to 6 medium-sized *Mus norvegicus*. None of the animals died from the effects of the agent, and when they were killed on the fifty-fifth day after the feeding were found to present no lesions.

The remaining work was done with rat virus, sometimes called "Mouratus." It is made by the same concern that makes the ratite. The rat virus comes in the form of a culture on a solid medium. The contents of three tubes was fed to 6 rats on May 26, 1908. Three of these rats died within thirty days. Only one was secured for examination before it had been mutilated beyond the possibility of making a satisfactory examination. This rat had a large yellow liver and a very large, dark, firm spleen. These appearances were probably due to the agent used and it is not unlikely that these 3 rats died from its effect. It will be observed that a very large dose was given. On another occasion four tubes of Mouratus were used for feeding 6 *Mus norvegicus*. One of the rats died on the fifteenth day, showing at autopsy an enlarged granular spleen and a granular liver. The other rats were alive and well at the end of thirty-four days when the experiment was discontinued.

Subcultures on broth were made from this preparation on three occasions, always well within the time limit on the label. The cultures were incubated in the dark, at room temperature, for forty hours on each occasion. Liberal amounts of the subculture were fed to a total of 31 rats. At the end of thirty days, it was found that only 2 of these rats had died. The others were alive and apparently well.

One objection to these agents which I have not seen stated is the following: The lesions caused by at least some of these members of the para-colon group may readily be mistaken for the lesions of plague, or it will perhaps be more accurate to say they give rise to lesions that create in one's mind a suspicion of plague infection, and I have had to put many a rat to the guinea-pig test in order to make certain that a Danysz infection was not associated with the infection of plague, or that a Danysz rat was not a plague rat. Of course, this is of no consequence except in a community where anti-plague measures are being taken, and an observer of limited experience who did not put a rat to a pretty rigid test would probably call some plague infected when in reality such is not the case.

In addition to the data set forth in this report, I have on several occasions fed the tissue of rats dead of Danysz infection to other rats, but have never succeeded in reproducing the disease. In other words, I have had no success whatever in raising the virulence by passage through animals.

OPINIONS OF OTHERS.

Kitasato,[a] 1906, states that the typhoid bacillus of the rat, which has been effectively used for killing field mice, has been found useless for house rats (*Mus rattus*) and therefore they no longer employ it.

Melvin,[b] 1908, reports that recently several new rat viruses were investigated in the Bureau of Animal Industry, with the result that the experiments clearly demonstrated the ineffectiveness and unreliability of the preparations tested.

Räbiger and Schwinning,[c] 1906, tested the culture discovered by G. Neumann and prepared by the joint stock company "Ratin" at Copenhagen by applying it to rat destruction. Of house rats 90 per cent died; black rats 42.9 per cent; while horses, dogs, goats, sheep, fowls, and pigeons suffered no harm. Of seven experiments practically carried out, six showed very good results; in one favorable results were absent, which agrees with the experiments made in Denmark. There it was likewise found that in individual locally limited places the rats were able absolutely to withstand the infection of ratin.

---

[a] Kitasato, S.: Combating plague in Japan. Philippine Journ. Sci., vol. 1, 1906, p. 465.

[b] Melvin, A. D.: Report of the Chief of the Bureau of Animal Industry for 1908. Washington, 1908.

[c] Räbiger and Schwinning: Versuche mit Ratin, einem neuen Ratten tötenden Bacillus. Mitth. d. deutsch. Landw.-Gesellsch., 1906, No. 18. Rev. by Ehrenberg in Centblt. f. Bakt., 2. Abt., vol. 18, 1907, p. 375.

Räbiger,[a] 1905, states that experiments with Loeffler's mouse typhus bacillus and the bacillus of Danysz virus have been carried to the conclusion that these bacterial preparations must be characterized as practically worthless.

In 1903 Neumann discovered in Denmark a rat-killing bacillus, which has been placed on the market by a society under scientific control under the name of "ratin." Feeding experiments with this bacillus were tried under conditions as nearly natural as possible upon white mice, gray house mice, long-tailed field mice, and gray rats. The experiment animals were fed with cubes of white bread impregnated with virulent cultures. White mice show the least power of resistance, since they die within six days; house mice died in six to nine days; the greater part of the rats died from the sixth to the sixteenth day after feeding; a small percentage lived. The long-tailed field mice, which are shown to be insusceptible to Loeffler's bacillus, also remained perfectly healthy after repeated feedings with bread infected with ratin.

Brooks,[b] 1908, reports the results of tests made with azoa on rats and mice, both in captivity and at large, but without any apparent discomfort to the animals. One of the tests is described as follows:

> A supply of the azoa was obtained direct from the laboratories of the manufacturers. On July 27, 1907, while the material was yet fresh, three young Norway rats were caught and kept confined in a large wire rat-trap. Beginning with the date given, and for a period of forty days thereafter, azoa was fed to the rats at intervals of a few days until ten 75-cent bottles had been consumed. The rats ate the cracked grain with which the virus was mixed very readily, and other food was denied them each time the azoa was given until every particle was eaten. At the end of the forty days the rats were still apparently in a healthy condition, and were removed from the trap and killed with a club.

Thompson,[c] 1906, states that three laboratory attempts have been made to destroy rats with imported strains of Danysz rat virus without success. Danysz having arrived at Sydney to study a similar method of destroying rabbits, the opportunity was taken of making a further attempt under his supervision with virus which had been imported and subsequently increased to the requisite degree of virulence, and had been placed at Thompson's disposition. The grounds of the Gladesville Asylum, a large institute for the insane, were chosen for the tests, which were conducted by Dr. R. J. Millard.

---

[a] Räbiger, H.: Ueber Versuche zur Vertilgung der Ratten durch Bakterien. Landw. Woch. f. d. Prov. Sach., 1905, p. 142. Rev. by Stift in Centblt. f. Bakt., 2 Abt., vol. 15, 1905, p. 86.

[b] Brooks, Fred E.: Notes on the habits of mice, moles, and shrews. A preliminary report. Bull. 113, W. Va. Univ. Agric. Exper. Sta., Morgantown, W. Va., Jan., 1908.

[c] Thompson, J. Ashburton: Report of the Board of Health on plague in New South Wales, 1906. On a sixth outbreak of plague at Sydney, 1906. Legislative assembly, N. S. W., 1907.

Millard summarized his result by stating that they can not be considered a satisfactory demonstration of the efficacy claimed for the Danysz virus. The results indicate a rapid loss of virulence, which must be obviated if this virus is to be of utility for rat destruction.

Again, in 1907, during the seventh outbreak of plague in Sydney, Thompson[a] had Millard test the preparations known as azoa and ratin. The laboratory results with these preparations were similar to those made by other investigators. Experiments made upon the ship *Hartfield* with azoa produced no considerable epizootic. The fatality among such rats as were infected was small. The practical tests with azoa upon several areas along the harbor front also resulted in disappointment.

The tests made with ratin upon the bark *Quilpe* produced no epizootic among the rats, and of the rats caught none of them showed infection; and the field experiment at Gladesville also resulted negatively so far as dead or sick rats were concerned. Nevertheless, there was apparently considerable diminution in the rat population of this area.

Foster,[b] 1908, reports unfavorably upon the results of tests made of some of these rat viruses. Laboratories were opened for the use of different parties who wished to make tests. The tests were conducted under their own supervision. The rats which were not fed on anything but grain died as freely as those that had been fed on azoa. So far as this preparation is concerned Foster states that it is absolutely useless to depend upon it.

Several reports are found in print in which the rat virus was laid out in certain localities and shortly afterwards the rats disappeared—at least no more were noticed. Such observations are apt to be misleading, for rats are migratory. They come and go, especially when disturbed. Further, it is doubtful, as far as plague is concerned, whether it is desirable to drive the rats away, for they may thus scatter the infection.

S. S. Mereshkowsky and E. Sarin[c] have recently studied ratin II, put out by a Copenhagen firm—"Bakteriologisches Laboratorium Ratin." The label upon the can of ratin II states that it is a bacterial culture, which produces in rats an infectious and fatal disease, killing them in two to eight days. The samples used by the authors were obtained as needed from the St. Petersburg representative of the firm. Feeding experiments carried out with gray rats (*Mus de-*

[a] Thompson, J. Ashburton: Report of the board of health on plague in New South Wales, 1907. On a seventh outbreak of plague at Sydney, 1907. Legislative Assembly, N. S. W., 1908.

[b] Foster, N. K.: The danger of a general plague infection in the United States. Proc. Confer. State and Prov. Boards of Health of N. America, 1908, p. 15.

[c] Ueber das Ratin II. Centralb. für Bakt. Parstk. u. Infectsk. Originale. Bd. 51. Heft 1. July 17, 1909, p. 6.

cumanus) showed that the rapidity and severity of the symptoms was proportional to the amount ingested. No positive results were obtained from the bacteriological examination of the bodies.

The ratin itself was sometimes found to be sterile, sometimes found to contain several varieties of bacteria and fungi, but no one variety was constantly present.

The potency of the ratin was not altered by exposure to 100° C. for one hour or 120° C. for five minutes. It was destroyed, however, by burning to an ash.

Identical poisonous results were obtained upon rats by feeding them with "Scilla maritina cum bulbo rubro."

Microscopical examination disclosed a small portion of a lamella, identified as belonging to the Liliaciæ, to which family squill belongs.

The authors conclude that ratin II is not a bacterial culture, but a poison rendered more dangerous to persons and domestic animals by the misleading statements of its makers.

PATHOGENICITY FOR MAN.

Loeffler[a] rather took it for granted at first that his *Bacillus typhi murium* was harmless for man. In order to remove the fears of the peasants in his campaign against the field mice in Thessaly he fed pieces of bread impregnated with the cultures to chickens, pigeons, dogs, hogs, horses, asses, sheep, and goats. No ill effects resulted. Further, some of the men who were distributing the prepared virus ate pieces of the infected bread in the presence of all and, it appears, suffered no ill effects.

Up to this time Loeffler had made no human experiments, but thought it improbable that his bacillus was harmful to man. He considered this view confirmed by the fact that he and his companions and still more so the peasants, handled large quantities of the virus without thorough disinfection of their hands and suffered no untoward effects.

Since that time, however, several mishaps have occurred. Instances of serious sickness and even death have been attributed to infection with the bacterial virus used for the destruction of rats.

Further, there is practically no difference between the *Bacillus typhi murium* and the para-typhoid bacillus which is the well-known cause of meat poisoning, and the *Bacillus enteridion* of Jarbues, which is associated with intestinal disorders.

It is true that persons have purposely partaken of the rat virus to prove that it is harmless to man; but it must be remembered that persons have partaken of cultures of cholera, typhoid, and other

[a] Loeffler, F.: Die Feldmausplage in Thessalien und ihre erfolgreiche Bekämpfung mittels des Bacillus typhi murium. Centblt. f. Bakt., vol. 12, 1892, p. 1.

bacteria without apparent injury to themselves. The flora and condition of the gastro-intestinal tract, the amount and virulence of the infection, and other conditions ("Y" and "Z" of Pettenkofer) play an important rôle in the production of these diseases.

The following references from the literature give the instances in which the *B. typhi murium*, or similar rat viruses, have been held responsible for the disease in man:

Trommsdorff[a] carefully studied 13 suspected cases near Munich in early May, 1903. Nine of these came into direct contact with the virus, three ate and associated with these, and the remaining one only smelled of the virus. One died from vomiting and severe diarrhea. The illness, which set in usually two days after contact with the virus, was for the most part simple diarrhea of two to seven days' duration (two to eight stools daily); in only three or four cases was there vomiting. The one fatal case seemed due to a confusing chain of circumstances, gross dietetic and alcoholic excesses in a weak, emaciated, presumably phthisical man whose three brothers had died of phthisis. One man, case No. 2 in the table, known to have eaten three pieces of infected bread, suffered only with a mild diarrhea.

In all cases errors of diet could be proven, and diarrhea was not uncommon at that season. The same physician attended during this period ten other cases of similar diarrhea in the vicinity having nothing to do with rat virus. The stools, however, did not have the same pathogenicity for mice, guinea pigs, or rabbits.

Trommsdorff specially points out the fact that the bacillus of mouse typhoid can multiply vigorously in the human intestine. It demands greater caution in the application of the cultures and more careful supervision over their use.

Finally, attention is invited to the fact that, contrary to the usual custom, the cultures of rat virus here used had been grown on milk, which might account for the increased virulence.

---

[a] Trommsdorff, R.: Ueber Pathogenität des Löfflerschen Mäustyphusbazillus beim Menschen. Münch. med. Woch., vol. 50, 1903, p. 2092.

The following table gives a brief summary of ten cases with the results of the agglutination tests:

Agglutination tests with serum of recovered cases, May 17, 1908.

Case.	How infected; symptoms.	Strains.	Serum dilutions. $\frac{1}{20}$	$\frac{1}{40}$	$\frac{1}{60}$	$\frac{1}{100}$	$\frac{1}{200}$
1 B. K...	(From this case stool 2.) Laid rat poison 5-2,5-5; some days later diarrhea; later vomiting; convalescence and recovery May 10.	A	+	+	+	±	0
		B	+	+	+	±	0
		C	+	+	+	±	0
		D	+	+	+	+	±
2 K. E...	Ate three pieces of infected bread May 2; mild diarrhea several days.	A	+	0	0	0	0
		B	+	±	0	0	0
		C	0	0	0	0	0
		D	+	±	0	0	0
3 H. B...	Brought the virus April 28; perhaps touched it; next day diarrhea and vomiting; recovery after several days.	A	+	0	......	......	......
		B	+	0	......	......	......
		C	+	0	......	......	......
		D	—	—	—	—	—
4 G. S....	Father of man that died; laid virus; two days later mild diarrhea for one or two days.	A	+	+	+	+	0
		B	+	+	+	+	0
		C	+	+	+	0	0
		D	+	+	+	+	±
5 J. K....	On April 27 laid virus; 2 days later diarrhea for several days.	A	±	0	0	0	0
		B	±	0	0	0	0
		C	±	0	0	0	0
		D	—	0	0	0	0
6 J. N....	Laid virus April 27; two days later had diarrhea for several days.	A	0	0	0	0	......
		B	+	+	+	±	......
		C	0	0	0	0	......
		D	+	+	+	±	......
7 G. I....	"Held" the virus April 28. Next day diarrhea for four days.	A	+	+	+	+	±
		B	+	+	+	+	±
		C	+	+	+	+	±
		D	—	—	—	—	—
8 H. R...	Ate and associated with persons who handled virus; diarrhea several days.	A	+	+	0	......	......
		B	+	—	0	......	......
		C	+	±	0	......	......
		D	—	—	—	......	......
9 K. S....	Associations as case 8; headache several days and loss of appetite.	A	+	+	+	+	......
		B	+	+	+	+	......
		C	+	±	0	......	......
		D	—	—	—	—	—
10........	Associations as case 8; diarrhea for eight days; vomiting several days.	A	0	0	0	0	......
		B	+	+	+	±	......
		C	0	0	0	0	......
		D	+	+	+	±	......

A=Strain from Loeffler.
B=Strain from market virus.
C=Strain from stool 1 (fatal case).
D=Strain from stool 2 (case 1 of table).
—=No test made.
0=Negative.
±=Slight.
Controls=Serum of five normal persons tested as above; gave in no case agglutination higher than 1:20.

The attending physician, noting that most of his patients had come into recent contact with rat virus (*B. typhi murium*) and suspecting that to be responsible, sent specimens of stools to the Hygienic Institute at Munich, where they were carefully examined with reference to this subject.

Organisms identical with Loeffler's *B. typhi murium* were isolated from the two stools examined and these cultures were compared with and conformed with a culture of *B. typhi murium* obtained from Loeffler and also a culture from the virus on the local market.

Two guinea pigs injected with cultures from the two stools gave, after the second injection, serum which agglutinated all the above organisms 1:200. A mouse typhoid serum obtained from Loeffler agglutinated all the above strains distinctly in dilutions 1:640 and slightly in 1:1280.

In conclusion, the author considers three possibilities: 1. The mouse typhoid bacillus was the cause of the illness. 2. The bacillus was accidentally present, having no part in the production of the symptoms. 3. The bacillus was able to multiply only in case preexisting intestinal trouble; then, however, causing the inflammation.

The case of Mayer, who became infected during the course of some laboratory experiments, is particularly instructive.

During an epidemic of mouse typhoid among his laboratory mice, evidently spread from some inoculated mice by ants, Mayer [a] who had personally handled the infected mice and their cages, became sick July 15, just seven days after the first appearance of the ants and after the observed rise in virulence of the mouse typhoid among the mice. His clinical history is as follows:

July 15: Weakness, epigastric pain, obstipation, temperature 37.7, pulse 90.

July 16: Slight diarrhea, increase of pain in region of trans-colon, temperature 38.3, pulse 98.

July 17: Diarrhea continued, pains increased—severe, chill in evening, temperature 39.1, pulse 102.

July 18: Obstipation, symptoms worse, chill again in evening, temperature 39.4, pulse 104.

July 19: Symptoms better, stools from purgative, evening temperature 36.9, pulse 68.

July 20: Left bed. Temperature and pulse normal, but weakness and slight epigastric pains continued till August 7.

---

[a] Mayer, Georg: Ueber die Verschleppung typhöser Krankheiten durch Ameisen und die Pathogenität des Löffler'schen Mäusetyphusbazillus für den Menschen. Münch. med. Woch., vol. 52, 1905, p. 2261.

Patient's serum agglutinated as follows:

	Typhoid.	Para-typhoid.	Mouse-typhoid.
July 23	1-50+	1-50+	1-250+
August 7	1-50+	1-50+	[a] 1-100+
August 16	1-50+	1-50+	1-50 +

[a] Slight.

The bacillus of mouse typhoid was isolated from the patient's stools July 21 and 23. Negative results thereafter. Examinations continued a month.

Same organism isolated from urine July 21. Negative thereafter.

The author concludes that the *B. typhi murium* is able to cause in man a rather severe acute illness of short duration.

Shibayama[a] gives the following report of outbreaks of human infection that have come to his knowledge in Japan, where mouse-typhoid virus has been used in considerable quantities.

Outbreak 1. In April, 1905, in a village of the Province of Saitama, 30 people became ill and 2 died with severe gastro-intestinal symptoms. Outbreak investigated by Dr. H. Sezuki, district medical officer, formerly of the Tokio Institute for Infectious Diseases.

It was found that all the 30 people had partaken of a dish of cooked vegetables served at a meeting of the town council, and that for application of sauce to these vegetables (after cooking) a wooden vessel had been used which two days before had been used for mixing mouse-typhoid virus with meal, without subsequent cleansing or sterilization.

The symptoms came on within twelve to forty-eight hours thereafter (usually twenty hours), chill or chilly sensations, rise of temperature to 38° or 39° C., or even to 40° C.; face flushed; pulse accelerated; great weakness; thirst, nausea, colicky pains in abdomen followed by severe diarrhea and vomiting. In general, the fever and diarrhea lasted two or three days; but malaise, anorexia, weakness, and mucous stools persisted for several days. The more severe cases showed choleraic symptoms of collapse. Two persons died in spite of medical treatment—a 6-year old boy and a man of 43, on the second and third day, respectively.

From the intestinal contents of these two cases, from the stools of several other cases, and from the remnants of the dish of vegetables in the wooden bowl an organism was isolated, which was demonstrated to be identical with the bacillus of mouse typhoid.

[a] Shibayama, G.: Ueber Pathogenität der Mäusetyphusbazillen für den Menschen. Münch. med. Woch., May, 1907, p. 979.

13429—10——14

These results were confirmed at the Tokio Institute for Infectious Diseases by Shibayama, by biological and immunizing tests.

Outbreak 2. On December 7, 1905, a peasant of a village in the Province of Miyaki brought home some mouse virus mixed with meal in cakes. This being mistaken for "mochi" was eaten about 2 p. m. the next day by two little girls, 3 and 8 years old, respectively, and their grandfather, 61 years old.

The man and the 8-year-old girl became sick at 9 p. m. the same day and the other child at about 3 p. m. on December 9. The symptoms in all cases were those of severe gastro-enteritis, as described under outbreak 1.

The man died December 12, the 8-year-old child died on the 10th; the 3-year-old child recovered after several days' illness. These three alone ate of the virus and no other persons in the house became sick.

No bacteriological examination was practicable.

Outbreak 3.—In a village of the Province of Iskawa, on April 22, 1906, a lot of rat poison was prepared by mixing agar cultures of the mouse-typhoid bacillus with meal and water in a large wooden bowl.

On April 24 there was a festival in the village at which about 170 persons were served with 240 pounds of rice, which, after being cooked, was kneaded into cakes in a wooden bowl. About 80 pounds of this rice was so kneaded in the bowl previously used for preparing the rat poison. Twenty to twenty-four hours later 120 people who had eaten of the rice became ill with the already described symptoms of gastro-enteritis, of mild type among the strong but severe among the children and old people. Eighty-nine cases came under medical treatment. There were no deaths, but a number of cases were confined to bed for a week or more; mild cases recovered in one to three days.

No bacteriological examination was made, but the physicians and town officials were unanimously of the opinion that the rat virus was the cause of the outbreak.

Outbreak 4.—A peasant of the province of Niigata brought home on May 14, 1906, some rat virus (cultures of mouse-typhoid bacilli mixed with meal) which he laid away. Two of his grandchildren—a boy of 5 and a girl of 7—together with the 4-year-old daughter of a neighbor, found and ate the rat virus. The next day all three children became ill with severe gastro-enteritis, of which the 4-year-old child died on the third day. The others recovered after several days of medical treatment.

Outbreak 5.—On May 16, 1906, a peasant in the province of Jamagata brought home some rat virus (6 c. c. cultures of mouse-typhoid bacillus mixed with meal), which was accidentally mixed with the feed given to a healthy horse next morning. The same evening the horse showed loss of appetite and appearance of sickness. Within two days he developed a severe enteritis, of which he died on the seventh day. The body was buried, but was dug up in the night by a laborer who cut off the hind quarters, took them home, and distributed the meat among friends and neighbors.

Within three days 34 persons who had eaten of this meat became ill with symptoms of severe gastro-enteritis. A 72-year-old man died after five days; the others recovered in three to eleven days.

This outbreak was investigated by Dr. H. Segawa, a medical officer of the province and former member of the institute at Tokyo, who isolated from the remains of the horseflesh by plate cultures and animal inoculations, an organism identical with the bacillus of mouse typhoid. A culture was sent to Shibayama, who carefully verified it (details not given).

Shibayama concludes: In all cases the close relationship between the bacillus of mouse typhoid and the illness was established; and he thinks this organism must be accepted as the direct cause of the outbreaks.

Referring to Loeffler's uniformly negative human experiments, he calls attention to known cases where men have taken virulent cultures of typhoid, diphtheria, etc., without infection. According to many bacteriological investigations, *B. typhi murium* is identical with the bacillus of enteritis. If it is proven that the latter is a cause of acute gastro-enteritis then the conclusion is likewise justified that the *B. typhi murium* is frequently pathogenic for man, causing an acute gastro-enterities.

Fleischanderl [a] reports six cases of illness—three severe and three mild—occurring in his practice in the latter part of April, 1908, presenting the following symptoms: Onset with rapidly increasing body pains, followed in a few hours by diarrhea, rise of temperature, and general prostration; in the next two or three days aggravation of the symptoms, fever (39° to 40° C.), copious diarrhea, vomiting (in one case), severe body pains, vertigo, and considerable prostration. Symptoms abated quickly in a few days, leaving considerable prostration, convalescence requiring two weeks in one case. In the less severe cases there was no fever, and the other symptoms were generally milder.

The simultaneous appearance of these and other similar rumored mild cases among the neighbors (about 20 in all) pointed to a common cause. It was found that three of the six cases were in people who had handled mouse-typhoid cultures the day before their illness, taking no precautions to avoid infection.

---

[a] Fleischanderl, Fritz: Mitteilung über einige Krankheitsfälle, hervorgerufen durch Mäustyphusbazillen. Munch. med. Woch., vol. 56, Feb., 1909, p. 392.

The other three occurred in a family which, on the day before the onset of the illness, had drunk raw milk obtained from a house where the rat virus had been used shortly before, and only three members of the family who drank the milk became ill.

In order to prove the etiology of these cases Fleischanderl, who had never suffered any intestinal troubles, had had nothing to do with any case of typhoid fever for a year, and was in excellent health, took a culture of the mouse-typhoid bacillus as used in the neighborhood, rubbed a glass rod over the surface, washed it off in a glass of water, and drank this before breakfast on the morning of May 3.

In twenty-two hours he experienced mild, increasing body pains, followed within a few hours by diarrhea, and a few hours later by slight chill, rise of temperature to 38.2, pulse 106, severe pains in body, and feeling of great weakness.

May 4, 9 p. m: Temperature 39.2° C., pulse 120. Height of symptoms.

May 5: Temperature 38.2° to 38.5° C., pulse 106 to 120. Other symptoms continued.

May 6: Temperature and pulse normal. All symptoms disappeared except weakness, which lasted two days.

Bacteriological investigations conducted by Herbert Berger in the K. K. Serotherapeutischen Institut and by Doctor Reichel, assistant in the Hygienic Institute of the University of Vienna, follow:

From the stools of one of the patients infected from milk an organism was isolated which, injected into mice (1 c. c. emulsion of forty-eight-hour culture), killed them in two to five hours. Mice infected by eating these dead mice died in thirty to forty-eight hours.

Control mice inoculated similarly with a culture of the market mouse-typhoid virus died in twenty to thirty hours, while the mice infected through eating these died after three to four days.

The following strains were used for cultural agglutination tests:

A. From stools of patient infected from milk.

B1. Market virus used in injecting mice.

B2. Market virus taken by author.

C25. From stools of author twenty-five hours after infection.

C55. From stools of author fifty-five hours after infection.

LL. Stock culture of Loeffler's mouse-typhoid bacillus.

LP. Stock culture of para-typhoid bacillus.

All organisms (A–C55) were demonstrated as motile bacilli, not liquefying gelatine, not forming lactic acid, and forming gas from dextrose.

The serum of a rabbit after two injections of LL agglutinated LL and LP in dilution of 1:1280, did not agglutinate A, B1, B2, C25, and C55.

Serum of rabbit after one injection of B2 agglutinated in 1:320 dilution A, B1, B2, C25, C55, and LL; did not agglutinate LP.

Serum of rabbit after one injection of C25 gave exactly similar results.

Doctor Reichel considers it proven that the organisms A to C55 are undoubtedly identical with Loeffler's bacillus of mouse typhoid, and distinct from para-typhoid bacilli. The author considers it proven that this bacillus was the sole cause of the cases of enteritis observed.

Recently Mallory and Ordway [a], in a paper read before the American Association of Pathologists and Bacteriologists held in Boston, reported that lesions analogous to the early stages of typhoid lesions may be produced in rats by the use of Danysz virus.

In view of these facts the statements of some of the advertising matter of certain rat viruses call for revision.

REFERENCES TO THE LITERATURE.

Loeffler,[b] 1889, gives an account of two spontaneous outbreaks among the mice kept at the Hygienic Institute at Griefswald. It was from these animals that he obtained and described the original *B. typhi murium.* He determined that the infection was by ingestion and that the organism was especially virulent for field mice. He described the organism in detail and also the lesions.

Laser,[c] 1892, reports that on the morning of February 6, 1892, 70 of the 76 field mice (*Mus agrarius*) used as experiment animals in the Hygienic Institut at Königsburg were found dead. A small bacillus twice as long as broad, displaying a very lively specific motility, was isolated from the spleen. It was tested upon animals and all the results compared with Eisenberg's tables and found to be closely allied to the bacillus of ferret plague (Ebert-Schummelbusch), to the bacillus of American swine plague (Billings), and to that of French swine plague (Chantamesse and Cornil).

Mereshkowsky,[d] 1893, isolated an organism at the Royal Bacteriological Institute at St. Petersburg from a stock of Zisel (*Spermophilus musicus*) among which a spontaneous epizootic had occurred. The author found this culture to be virulent for domestic and field mice.

---

[a] Mallory, F. B., & Ordway, T.: Lesions produced in the rat by a typhoidlike organism (Danysz virus). Journ. Am. med. assn., vol. 52, May 1, 1909, p. 1455.

[b] Loeffler, F.: Ueber Epidemieen unter den im hygienischen Institute zu Griefswald gehalten Mäusen und über die Bekämpfung der Feldmäusplage. Centblt. f. Bakt., Orig., vol. 11, 1898, p. 129.

[c] Laser, Hugo: Ein neuer für Versuchsthiere pathogener Bacillus aus der Gruppe der Frettschen-Schweinseuche. Centblt. f. Bakt., Orig., vol. 11, 1892, p. 184.

[d] Mereshkowsky, S. S.. Ein aus Zieselmäusen ausgeschiedener und zur Vertilgung von Feld-resp. Mäusen, geeigneter Bacillus. Centblt. f. Bakt., Orig., vol. 17, 1895, p. 742.

Zupnik,[a] 1897, states that Joseph, of the Agricultural Institute of Breslau, in 1882 originated the use of favus fungus for the destruction of mice. Zupnik tested *B. typhi murium* and Danysz virus upon mice. No experiments with rats.

Issatschenko,[b] in 1898, described briefly a bacillus obtained by him from gray rats. Recent investigation showed this bacillus to be very virulent for rats and mice, but harmless for the different species of domestic animals. Four hundred and forty-three experiments were made upon rats with pure cultures of the bacillus combined with dough and fed to the rats. He gives a table showing that the mortality occurred in 431 rats at an average of ten and one-half days. The greatest mortality occurred during the first fifteen days (84.2 per cent), with the greatest number on the seventh day (20.1 per cent).

Danysz,[c] 1900, isolated a cocco-bacillus during an outbreak of spontaneous disease amongst field mice which presented the general characteristics of the colon bacillus and to this extent resembled Loeffler's bacillus (*B. typhi murium*), and which from the beginning exhibited some pathogenicity for gray rats (*M. decumanus*). Of ten such rats fed upon a culture of this organism, two or three died, while others that had fallen sick recovered and the same remained well. This small mortality offered some hope that it would be possible to increase the virulence of the bacillus by ordinary methods; that is, passing it from rat to rat. It was found, however, that the opposite was true; the virulence was always weakened by this process regardless of the method of administration. Thus in every series the first culture killed the animals in seven to twelve days; occasionally after one or two passages five to seven days; but subsequent passages decreased the virulence so that none died.

The general result is that it is difficult to maintain the virulence of the cocco-bacillus of the rat or to increase it when it is found to be small. It can only be effected by constantly making a large number of experiments and frequently testing the virulence of the culture. Danysz succeeded in keeping up a supply of cultures of sufficient strength for eight years. In 60 per cent of the operations where this culture has been used it has been successful in causing the absolute disappearance of the rats. In 15 per cent the result was entirely negative, and in the remaining 25 per cent there was a large diminution.

---

[a] Zupnik, Leo: Ueber die pratische Verwendbarkeit der Mäuse bacillen inbesondere des Loeffler'schen *Bacillus typhi murium*. Centblt. f. Bakt., Orig., vol. 21, 1897, p. 446.

[b] Issatschenko, B.: Untersuchungen mit dem für Ratten pathogenen Bacillus. Centblt. f. Bakt., Orig., vol. 31, 1902, p. 26.

[c] Danysz, J.: Un microbe pathogène pour les rats (*Mus decumanus* et *Mus rattus*) et son application à la destruction de ces animaux. Ann. Inst. Pasteur, 1900, vol. 14, p. 193.

Oettinger,[a] in 1903, increased the virulence of the Danysz bacillus by growth in an egg rendered alkaline after the method previously introduced by Wiener.

Pfreimbtner,[b] 1904, sees the reason for a partial failure in the application of Loeffler's bacillus to the destruction of field mice. In the use of a solid medium (agar-agar), upon which the bacterial cultures only grow upon the surface, too few bacteria are transferred to the pieces of bread, and consequently too few virulent bacteria are consumed by the mice. An active infection depends not upon the existence of virulent bacteria, but rather upon the entrance of a definite number of virulent bacilli.

The author used skimmed milk as a nutrient medium and describes a series of 9 experiments and gives an estimate of the cost of the process with the use of milk instead of agar. The advantage of the use of milk is in the greater certainty of the results and cheapness as compared with other methods. The bread cubes impregnated with skimmed milk were well taken by the mice and desiccation of the cultures, which not infrequently occurs in the use of more solid media, is excluded. Notwithstanding the excessive thinning, the liquid still contains many virulent bacilli. The washing out of bacilli after rain is slightly less possible as in the use of the more solid media. The action of light, where the bread cubes contain many bacilli, is insignificant, and hence the carrying out of the process in the daytime is made possible. Milk is easily obtained and the thinning and application less bothersome. Finally the author expresses himself against the view that the *B. typhi murium* causes serious diseases in man.

Teichert,[c] 1905, speaks of Loeffler's mice typhus bacillus and Pfreimbtner's method of growing it upon sterilized skimmed milk. A number of experiments carried out at the bacteriological laboratory of the Vreschen experiment station shows the utility of Loeffler's bacillus for the destruction of house and field mice. The long-tailed field mouse was, on the other hand, not harmed by it.

Bahr,[d] 1905, gives a complete and satisfactory summary of the literature upon the subject of the destruction of rats and mice with bacteria, including original work of his own.

---

[a] Oettinger, M.: Ueber die Wienersche Methode zur Virulenzsteigerung der Danysz Bazillen. Munch. med. Woch., vol. 1, 1903, p. 324.

[b] Pfreimbtner, J.: Erfahrung über des Loeffler'schen Infektionsverfahren zur Bekämpfung der Mäuseplage in einer neuen Art der Anwendung. Fühlung's landw. Zeit., 1904, p. 619. Rev. by Schander in Centblt. f. Bakt., 2. Abt., vol. 15, 1905, p. 502.

[c] Teichert: Die mechanischen, chemischen und bacteriellen Kampfmittel gegen Ratten und Mäuse. 2. Teil: Die Bekämpfung der Mäuse. Fühlung's landw. Zeit., 1905, No. 16. Rev. by Ehrenberg in Centblt. f. Bakt., 2. Abt., vol. 15, 1905, p. 503.

[d] Bahr, L.: Ueber die zur Vertilgung von Ratten und Mäusen benutzten Bakterien. Centblt. f. Bakt., Orig., vol. 39, 1905, p. 263.

Zielander,[a] 1908, obtained fairly good results with Danysz virus in the laboratory, also with ratin. No fixed tests were recorded.

RÉSUMÉ.

Rats are notoriously resistant to bacterial infection. Even plague usually fails markedly to diminish their prevalence. An epizootic of bacterial nature, therefore, can not be classed with the natural enemies of the rat. We are not surprised, then, to learn that the bacterial viruses have signally failed to accomplish their mission.

These bacterial viruses belong to the colon-typhoid group of organisms. They are either identical with or closely related to the original bacillus of mouse typhoid discovered by Loeffler, or the paratyphoid bacillus type B, which is frequently the cause of meat poisoning, or the *Bacillus enteritidis* of Gærtner, which has been associated with gastro-intestinal disorders.

The claim that these rat viruses are harmless to man needs revision, in view of the instances of sickness and death reported by various observers. The pathogenicity for man depends upon the virulence of the culture, the amount ingested, the nature of the medium in which it grows, and many other factors.

Danysz virus is pathogenic for rats under laboratory conditions, but has feeble powers of propagating itself from rat to rat. It rapidly loses its virulence, especially when exposed to light and air. The result depends largely upon the amount ingested. The other viruses have proven even less satisfactory.

Under natural conditions these rat viruses may be likened to a chemical poison, with the great disadvantage that they rapidly lose their virulence and are comparatively expensive. They also have the further disadvantage that chemical poisons do not possess of rendering animals immune by the ingestion of amounts that are insufficient to kill or by the ingestion of cultures that have lost their virulence.

---

[a] Zielander: Der Rattenbacillus als Rattenvertilgungsmittel. Arb. a. d. k. Gesndhtsmte., Berl., vol. 28, 1908, p. 145.

PLAGUE ERADICATION IN CITIES BY SECTIONAL EXTERMINATION OF RATS AND GENERAL RAT PROOFING.

By Victor G. Heiser,
Passed assistant surgeon, U. S. Public Health and Marine-Hospital Service, chief quarantine officer and director of health for the Philippine Islands.

The health officials of the city of Manila, P. I., for the five-year period from 1900 to 1905 made most valiant efforts to destroy the rats of the city; approximately $15,000 were paid in rat bounties and $325,000 in salaries and wages and other expenses for rat catching, but at the end of that time the rats were apparently as plentiful as before and the plague was still present. The experience in Tokio and Osaka had been practically the same. Professor Kitasato expressed the opinion that a given city could only have up to a certain number anyhow, because further increase was limited by the amount of available food, and when the limit had been reached the rats commenced to eat one another, which prevented more than a certain number ever being present, and that the increase by breeding was about as rapid as any method of destruction which had yet been tried.

The following plan was then tried, and the plague among human beings soon disappeared, there being no cases since April, 1906; and it has been eradicated among rats each time that it has made its appearance.

A list of the places at which plague-infected rats were found was made. Each was regarded as a center of infection. Radiating lines, usually five in number, were prolonged from this center, evenly spaced like the spokes of a wheel. Rats were caught along these lines and examined. Plague rats were seldom found more than a few blocks away. The furthermost points at which infected rats were found were then connected with a line, as is roughly shown in the diagram on page 206 (Fig. 59.)

The space inclosed by the dotted line was regarded as the section of infection. The entire rat-catching force, which had heretofore been employed throughout the city, was then concentrated along the border of the infected section; that is, along the dotted line. They then commenced to move toward the center, catching the rats as they closed in. Behind them thorough rat proofing was carried out. One section after another was treated in this way until they had all been wiped out. Once weekly thereafter rats were caught in the previously infected sections and at other places which were insanitary and which had been infected in years gone by. This was continued for one year.

The city was then divided as is shown in the diagram facing this page, and rats are caught once weekly at each point at which the lines intersect and sent to the laboratory for examination.

In addition, sanitary inspectors are instructed to bring in dead rats

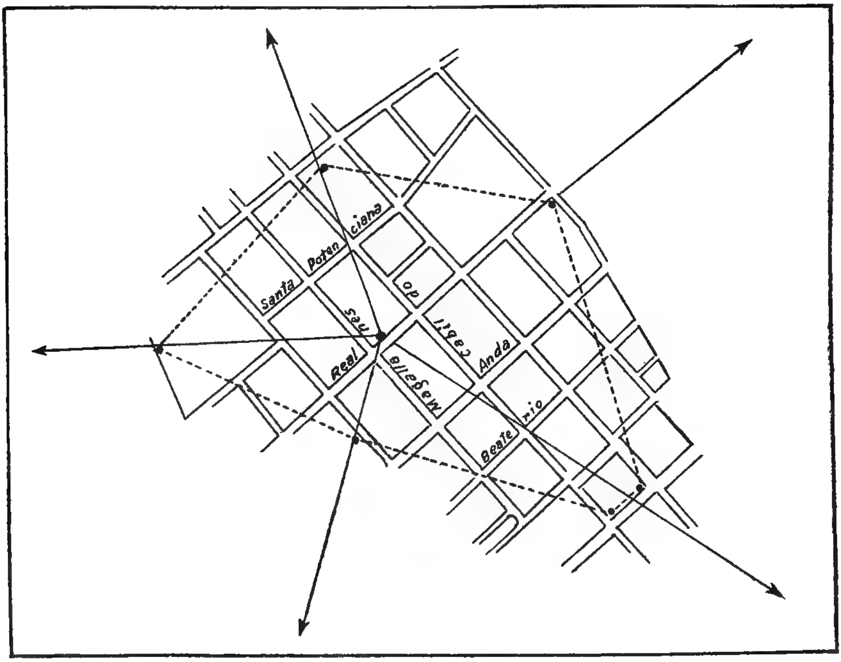


FIG. 59.—Isolated plague-infested center, Manila, P. I.

which have evidently died of disease, and more detailed rat catchings are made along the water front.

It is understood of course that rat proofing of the entire city should be thoroughly carried out and constantly maintained.

CONCLUSIONS.

1. Since the above system was adopted plague has disappeared in the city of Manila; among human beings in 1906; among rats in 1907, and it has not reappeared since.

2. That the cost is only a small fraction of that of general rat extermination.

3. That the plan is thoroughly practical for any kind of a city.

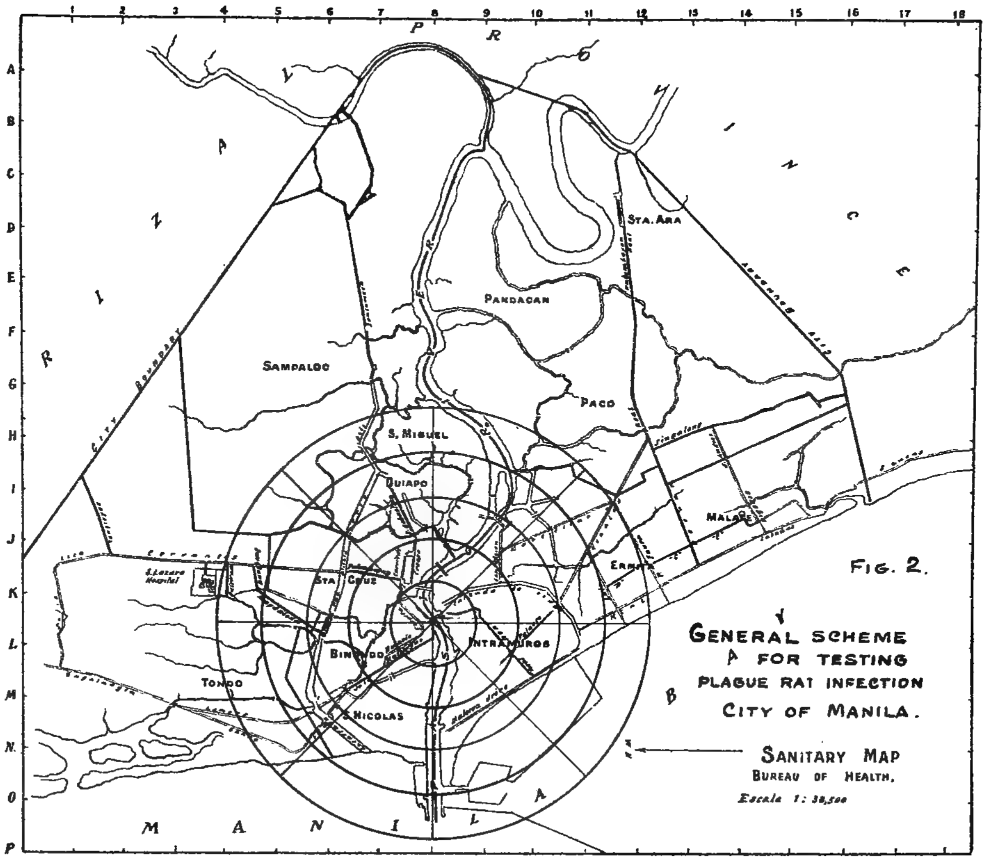


FIG. 2.
GENERAL SCHEME FOR TESTING PLAGUE RAT INFECTION
CITY OF MANILA.
SANITARY MAP
BUREAU OF HEALTH.
Escala 1: 38,500
RIZAL PROVINCE
MANILA
STA. ANA
PANDACAN
SAMPALOC
PACO
S. MIGUEL
QUIAPO
MALATE
ERMITA
STA CRUZ
INTRAMUROS
BINONDO
TONDO
S. NICOLAS
S. Lazaro Hospital
City Boundary

THE RAT IN RELATION TO SHIPPING.

By William C. Hobdy,
Passed Assistant Surgeon, Public Health and Marine-Hospital Service.

Since men first went down to the sea in ships the rat's voyage-making tendencies have been known, and their fecundity is as well established as their fondness for travel. The record does not state that there were more than a pair on the ark at the beginning of her voyage, but the chances are better than even that her skipper began that voyage with more rats than his manifest showed; but whether he did or not, we can be sure he had more at the end of the voyage than at the beginning. Whether or not succeeding generations inherited from their forbears on the ark this well-known wanderlust is undetermined, but it is a fact that the intimacy and companionship established and begun then have been persistently maintained by the rat ever since. His travels have been coextensive with man's, until to-day there is not a port on earth where the rat is not present. Any exception to this statement simply proves the rule. The rat is cute; he knows when he is well off and his absence from a port does not prove that he has not been there, but that he has been too intelligent to follow man ashore. In establishing this shipboard intimacy there has been no "by your leave" courtesy on his part either; he goes without consent—against orders, even—and man's ingenuity has as yet discovered no effective means of keeping him off. This is not surprising when the rat's ability as a rope walker is considered. I have seen a rat gallop with all appearance of enjoyment along an inclined electric cable from a church steeple on one side of a street into the second story of a hotel on the other. Others have been seen traveling along the telephone wires from house to house, and on shipboard they frequently have runways on small pipes along which they scurry in perfect security. When a ship is fended off 6 feet from the dock and her gang plank is lifted or guarded she is still freely accessible, because all her mooring lines are only so many highways along which rats can and do pass with ease and in perfect safety.

This fondness for ships and sea travel is shared by the various species of the rat family, but the *Mus norvegicus* has earned the reputation of being the greatest traveler of them all. He almost invariably predominated among those killed by fumigation on shipboard. That he finds life on shipboard easy and the conditions satisfactory is proved by the numbers that are destroyed from time to time by fumigation. While in charge of the outgoing quarantine work in San Francisco the chief engineer of a small lumber carrier called to book his vessel for fumigation. The vessel was small, only 260 tons, and carried nothing but lumber and her own ship's stores, but the chief declared she was overrun with rats, and to prove it showed where they had eaten the patches from his shoes. He declared they robbed him of his sandwich when he came off watch, and requested me to give her a thorough fumigation. This was done. The next morning the agent of the vessel phoned to ask how I measured rats, stating that on this vessel they had collected "a barrelful and seven." Three hundred and ten on a little vessel of only 260 tons burthen.

On another vessel after one fumigation 100 were collected immediately after fumigation, but a few days later, when the vessel was undergoing extensive repairs, 425 others were found—a total of 525 on one small vessel. These numbers are small, however, when compared with the results obtained on others, i. e., on grain-carrying vessels. For instance, a vessel was fumigated some years since in Bombay where 1,300 were destroyed at one time, and the *Minnehaha*, a new vessel only nine months in commission, on fumigation in London, England, in May, 1901, yielded a bag of 1,700 rats.

ADAPTABILITY OF THE RAT TO HIS SURROUNDINGS.

In addition to his qualities as a sailor and tight-rope walker, the rat has the power of adapting himself to most unusual conditions and surroundings. At the beginning of the outgoing work in San Francisco it was urged that rats either could not or would not live on any part of tank ships engaged exclusively in carrying oil, owing to the fumes and vapors that permeated the entire vessel. This statement was unquestionably correct for those compartments in which the oil itself was stored or carried. It was not true, however, for the superstructure of these vessels, for on one of the oil carriers 60 rats were found after one fumigation, and of the thirty or more vessels of this class that were regularly fumigated in San Francisco, although the odors of oil or gasoline were quite strong in the living compartments, not one was found that did not harbor rats. Still more remarkable, as illustrating the rat's adaptability, was the fact that from the large refrigerating plants which some vessels carried and in which fumigation had not been practiced for a long time rats were obtained that had grown a fur an inch and a half long to protect themselves from the cold.

DAMAGE TO CARGO.

That rats on shipboard in any such numbers as mentioned above must do much damage to cargo can not be doubted.

Inquiry as to the extent of this damage showed that there were no data on the subject. That such damage was common and considerable, however, was revealed by the fact, elicited by these inquiries, that nearly every steamship company on both the Atlantic and Pacific took precautions both to keep rats from getting on board and to destroy them after they did. One example will show what damage may occur. The British steamer *Gadsby*, on a voyage from India to Antwerp, covering a period of twenty-nine days, had 44,000 out of 46,000 bags of wheat cut by rats, with an estimated damage of $2,200.

The constant and almost universal presence, then, of rats on shipboard can not be doubted, and if it could the results of fumigation, wherever practiced with SO_2, would serve to settle the question, for they are found under all conditions, even on the most unlikely vessels.

How do these rodents gain access to a vessel? It has been the custom to assume that they came on board from the docks over the side when this was possible, and when it was not, as when the vessel was fended off or stood too high out of the water, that they made use of the gangways, mooring lines, hawsers, etc., as avenues of communication. It is still the practice, therefore, in enforcing antirat precautions, to compel the ship to fend off 6 feet from the dock, to wear rat funnels on all lines, and to raise the gangway from the dock at night. Just a word as to these precautions. The most practical fender is a floating one made of heavy timbers either bolted together into a solid frame, with the necessary cross braces bolted in, or made up of logs or spars chained together. They should be long enough to distribute the pressure of the vessel as the tide moves over a number of piers or piles so that the weight does not bear, through the medium of these fenders, on just one or two of the wharf foundations. Such a fender will stay in position, will do no damage to the vessel, and no matter how great the amplitude of the tide may be, will always remain below the ship's gunwale and can not therefore be utilized by rats as a means to get on board. Large vessels require at least two. Small ones need but one, and it was found in San Francisco, in the case of those vessels changing their mooring several times daily, that this one could be carried from wharf to wharf by the vessel without trouble or delay simply by lashing it edgewise outside on top of the guard.

Funnels should be of heavy galvanized iron, circular in shape, and not less than 36 inches in diameter. The spout of the funnel should be 3 inches in diameter and should be at least 18 inches long. The flange of the funnel should be soldered to this 18-inch pipe at its middle so that the spout projects 9 inches out of the funnel and 9 inches into it.

When the two halves of the funnel are brought together this spout or tube is occupied by the line or hawser to be protected, and by lashing this tube to the hawser the funnel is held in position and prevented from lying down. Such a funnel should be put on every line from the vessel to the dock, and when the tube does not fit the line the latter should be parceled before the tube is lashed to it.

These, together with raising the gang plank from the dock at night, make up the precautions ordinarily taken to prevent the rats from getting on ships. As stated above, they are based on the assumption that these are the common avenues of entrance. That these precautions do much good can not be doubted, but in the writer's opinion they do not entirely cover the case, for there remains one other road of ingress, one of the important, if not the most important, which these precautions do not and can not block and through which rats constantly get on board, and that is through the medium of the cargo itself. There is at present nothing to prevent access in this manner to a vessel and the route is so easy that there can be no doubt that whole families of rats are carried on board in this way. In fact some articles of cargo offer inviting harbors and homes to rats, particularly when these articles have been stored for a time in rat-infested warehouses. Among such articles of cargo may be mentioned crockery or china packed in hay or straw or excelsior and loosely crated; various articles of furniture packed in excelsior, wrapped in gunny, and loosely crated; wheat, corn, oats, peanuts, or barley when shipped in bags; and matting in hollow rolls when sewed up in gunny. Any of these articles could easily become the home of even an entire rat family after having been stored for a time prior to shipment in a rat-infested warehouse. As a matter of fact, the last plague rat discovered in San Francisco was found in a bag of peanuts on the third floor of a warehouse.

That rats are thus carried on board is absolutely certain in my opinion. In the recent antiplague campaign at San Francisco there were ample opportunities for observations along this line, and in no other way can the presence of rats in troublesome numbers on board certain vessels be explained. These vessels were new, were freed from rats by careful and repeated fumigation, and between these acts touched at no wharves save in Honolulu and San Francisco, where constant antirat precautions were observed. And yet on their second trip (about five months after the fumigation had been discontinued) they were badly rat-infested. Of course, by no means had all these rats been carried on board in cargo, but the original patriarchs of the colony had, after which, as is probably the case in all ratinfested ships, their natural prolific characteristics did the rest.

In the same way, too, rats are carried from ship to shore and the truth of Kitasatso's aphorism that "wherever ships go, plague will go," at once becomes apparent, and any regulations to prevent the introduction of such vermin and the plague which they may carry to be effective must include the inspection of cargo to insure its freedom from rats, this inspection to be made just before it goes on board.

The relation these rodents bear to plague and the part they play in its transmission have been thoroughly discussed and set forth in another article in this work. The work of Ashburton Thompson in Australia and of the British Medical Commission in India was a scientific demonstration that plague was primarily a rat disease transmitted by fleas, while McCoy in the United States has gone further probably than anyone else in demonstrating the manner in which the flea does this work. The importance of this relation is emphasized and the difficulty of ridding a port of pest infection is explained by a fact, first observed so far as I know by Klein, of London, that rats suffer from a chronic form of pest, not fatal, at least for a long time, and during the course of which the rat may exhibit practically his normal activity. This fact then, that plague is primarily a rat disease and that it may occur in the rat in a chronic form, shows how great the danger may be from their presence on shipboard, explains why it is that where ships go plague will go, and emphasizes the importance of destroying them on shipboard apart from the damage and loss which their presence entails.

So important is this and so preeminent is the rôle played by the rat in plague transmission and propagation that I believe regulations should demand that all ships be disinfected at least three times, and better still, four times, a year, for the destruction of rats. If this precaution were taken, and if to it were added an inspection of cargo at the port of embarkation to insure its freedom from rats, I believe the disinfection of cargo could be entirely dispensed with. It is infectious only in so far as it harbors rats, and if these are not present disinfection, in my opinion, does as little good in preventing plague as dipping ballast did in preventing yellow fever.

FUMIGATION.

Once the rat has gained access to a vessel, what is the best method of getting rid of him?

There are several methods, all of which are effective if properly used, and all of which depend on sulphur dioxide as the destructive agent. The following are mentioned: Pot and pan, sulphur furnace, Clayton system, and Marot system. A choice of one of these methods will be determined by the cost, the rapidity of fumigation desired, and the condition of the vessel, whether empty or loaded. No matter which method is selected, to be effective the sulphur dioxide must be simultaneously delivered to or generated in every compartment on the vessel.

For an empty vessel nothing is so satisfactory as the pot and pan method of generating the gas. It has the following advantages; is more rapid than any other, is cheaper, is more effective, and is equally applicable to the largest and the smallest vessel afloat. With a sufficient number of pots and pans 3,500 pounds of sulphur can be burned just as quickly as 100. Ten pounds of sulphur in each of 350 pots will be consumed just as quickly as will 10 pounds in any one of that number, namely, in less than five hours, a fact which was demonstrated over and over in the outgoing work in San Francisco.

At the beginning of this work it was thought a 2½ per cent gas with three hours' exposure would be sufficient. Practice proved, however, that this was not effective and the strength of gas was increased to 3 per cent and the exposure to five hours which a test, extending over twelve months and embracing over 3,000 vessels, proved to be ample.

The best pot in which to burn sulphur is 6 inches deep, has a flare of 6 inches—that is, the diameter at the top exceeds the diameter at the bottom by that much, is from 16 inches to 24 inches in diameter at the top and has four hemispherical legs about the size of half a billiard ball. These pots when in use are set in a galvanized iron tub. These tubs contain a little water, and are of a diameter 6 inches greater than the top of the pot. The hemisperical legs of these pots will not punch holes into the tub. The pots are filled with sulphur, which is hollowed out into a little crater at the top, into which crater from 4 to 6 ounces of alcohol are poured and when all are ready a lighted match is dropped into each little crater and the compartment is closed.

In actual practice it was found that an exposure of five hours to a 3 per cent gas would not destroy all the rats in absolutely every case. Some ships afford better hiding places than others, and on these an occasional rat would escape. It was the custom, however, to fumigate all vessels every thirty days and after the third fumigation, on vessels that did not carry general cargo, no more rats were obtained, though the fumigations were continued for a number of months.

On those vessels that carried miscellaneous general cargoes a few rats were found after almost every fumigation. These vessels touched no wharf from the time they left San Francisco until their return, except for a short time in Honolulu, where adequate precautions were observed, and it is difficult to understand how these rats got on board if they were not carried on in cargo.

For vessels with cargo in their holds the pot and pan method is dangerous owing to the possibility of fire. For these vessels one of the other methods of generating the sulphur gas must be used. This involves the use of an expensive plant consisting of a furnace, cooling chamber, blower, or fan, and a system of mains and delivery pipes by means of which the gas is delivered to the various holds and compartments of the vessel. To be at all effective the gas must be 4½ per cent strength, with at least twenty-four hours exposure. The one recommendation of such a system is its freedom from danger by fire. It is too slow; the pipes, even where 6 inches in diameter, are liable to clogging with sublimed sulphur, an inevitable result if the fans are driven too rapidly, and it is not possible to do more than one or at most two ships at a time. The inadequacy of such a method when compared to the work done in San Francisco where we averaged over nine vessels every day for almost fourteen months is at once apparent. Many ships now carry their own disinfecting plants, by means of which not only is sulphur dioxide generated and pumped into a compartment, but at the same time also the air of this space is sucked out. This principle is excellent, but in its application the machines used are wholly inadequate, having a very limited sulphur capacity per hour and equipped with delivery pipes in many instances only 2 or 3 inches in diameter. It would be a matter of days to disinfect some of these ships with the machines they carry. In San Francisco we again and again used pots and pans to fumigate these vessels, including the very compartments in which their own machines sat doing nothing.

The Marot system of generating the gas from compressed liquid sulphur dioxide has in this country been found too expensive to apply to vessels. Probably no system will effectually destroy all the rats on a cargo-laden vessel.

SUMMARY.

To summarize then:

1. The rat is found on all vessels, sometimes in enormous numbers, and is able to adapt himself to all sorts of conditions. He either gets on board himself or is carried on in cargo. Owing to his sea-going tendency, his distribution is world-wide.

2. On shipboard, to live he must do damage to either cargo or stores, or both.

3. Plague is primarily a rat disease; it may exist in the rat in a chronic form. Hence where ships go plague will go sooner or later.

4. To prevent the ingress of rats and the consequent spread of plague, ships should observe antirat precautions, and cargo inspection should be included in these.

5. At stated intervals, three or, better still, four times a year, all vessels should be fumigated for the destruction of rats.

6. On empty vessels this can best be done by generating sulphur by the pot and pan method.

7. On laden vessels some special apparatus must be used to generate the gas. A longer exposure is required, at least twenty-four hours, and the gas should be 4½ per cent strength instead of 3 percent. It is extremely difficult by any method to kill all the rats on a cargo-laden vessel.

13429—10——15

THE RAT AS AN ECONOMIC FACTOR.

By DAVID E. LANTZ,
Assistant Biologist, United States Department of Agriculture.

INTRODUCTION.

The world has rightly learned to dread rats as disseminators of disease, and recent efforts to rid cities of the pests have resulted chiefly from sanitary considerations. Yet the material losses due to depredations of rats are now, and always have been, a sufficient argument for their destruction. The requirements of sanitation and public health are slowly bringing to pass what economic interests failed to accomplish, namely, a general recognition of the fact that the rat is a standing menace to prosperity. To point out some of the many ways in which rats inflict injury and the extent to which they drain the resources of the people is the object of the present chapter.

UTILITY OF THE RAT.

Do rats serve any useful purpose? With very slight reservation, the question may be answered in the negative. There have been times and places in which the rat's work as a scavenger accomplished good, but modern methods of garbage disposal are superseding the feeding it to rats.

It was Robert Southey, the poet, who, nearly a century ago, humorously suggested as the first three steps to eradicate rats—first, introducing them as a table delicacy; second, utilizing the skins; and third, inoculating them with a contagious disease.[a] The last of these plans is now receiving considerable attention from bacteriologists, but the others, for obvious reasons, have been neglected.

It is true that under exceptional circumstances the rat has been a source of human food. The principal instances on record were during the siege of Paris in 1870, and during the siege of the French garrison at Malta, 1798–1800, when food was so scarce that rat carcasses brought high prices. Another was on board the ship *Advance* during an

[a] Omniana, vol. 1, p. 25, 1812.

arctic winter, when Doctor Kane attributed his entire immunity from scurvy to his diet of fresh rats, of which none of the other members of the party would partake.[a]

The statement is often made in newspapers, and even in encyclopedias, that in Europe, and especially in France, rat skins are extensively used in the manufacture of gloves. The late Frank T. Buckland, about a half century ago, made diligent inquiry in London, and through friends in Paris and other places on the Continent, but found no confirmation of such statement. He concluded that either rat skins were not used for making gloves or the manufacturers were unwilling to acknowledge such a use.[b] Personally, the writer has been unable to learn of any demand or market for rat skins at the present time. They are not strong, and the fur is of inferior quality. The occasional finding of one or more rat skins in the fur lining of coats is probably to be explained by the fact that they are sometimes included in lots of small muskrat skins (''kitts'') and overlooked by the buyer.

DESTRUCTIVENESS OF THE RAT.

Rats inflict injury in a surprising number of ways, and before an attempt is made to consider the magnitude of the losses due to these animals a statement of the nature of their depredations should be made.

DAMAGE TO GRAINS.

Cultivated grains are the favorite food of rats. The animals begin their depredations by digging up the newly-sown seed. They eat the tender sprouts when they first appear, and continue destroying the plants until the crop matures. They then attack the grain itself, and after harvest take toll from shock, stack, mow, crib, granary, elevator, mill, and warehouse. When rats are abundant their depredations amount to an appreciable percentage of the entire yield of grain, and in exceptional cases whole crops have been ruined.

INDIAN CORN.

Probably this crop suffers greater injury from rats than any other in the United States. To some extent the animals dig up newly planted corn, but their injury to the maturing grain is far greater. They are especially fond of corn in the milk stage, and often climb the upright stalks and strip the cobs bare. In this way sometimes whole fields are destroyed.

Corn in the shock is often attacked by rats, especially in parts of fields adjacent to hedges, drains, or embankments that afford shelter

---

[a] Second Grinnell Expedition, vol. 1, p. 393, 1856.

[b] Curiosities of Natural History, first series, p. 83, 1857 (Reprint 1900).

for the animals. A pair of rats often make a corn shock their home, and soon destroy both grain and fodder.

Corn in cribs is often damaged by rats. Many cribs are built close to the ground, and rats take up their abode under the floor. They soon gnaw through the wooden barrier and have free access to the grain. They shell the corn and eat the soft part of the kernels, wasting much more than they eat. They carry the grain into underground burrows and bring up moist soil from below, which in contact with the grain makes it moldy and unfit for market or for feeding to stock. A number of farmers have reported the loss by rat depredations of from a fifth to a half of the contents of a large corn crib during a single winter.

An Iowa farmer, writing to an agricultural journal, relates the following experience:

> We had about 2,000 bushels of corn in three cribs to which rats ran, and they ate and destroyed about one-fourth of the corn. Much of it was too dirty to put through the grinder until it had been cleaned an ear at a time. All the time we were poisoning and trapping the rats. We killed as high as 300 rats in two days and could hardly miss them. They destroyed more than enough corn to pay taxes on 400 acres of land.[a]

Throughout the United States, but especially in the West and South, corn is often stored for months in rail or other open pens, to which rats have free access. Often the loss in a single season would pay for the construction of rat-proof cribs, or at least for wire netting, that would fully protect the crop.

SMALL GRAINS.

Much has been written about the rat as a house and barn pest, but its depredations in the fields have usually been overlooked. In some localities the common rat, as well as the house mouse, swarms in the fields, especially in summer, and subsists entirely upon the farmers' crops.

Stacked grain is peculiarly exposed to rat depredations. In the United States, although the cost of protection is small, rats are seldom fenced away from stacks, and, if threshing is delayed, serious loss results. Often, at the removal of a stack, large numbers of rats are discovered, which have been living at the expense of the farmer. As early as 1832 a farmer in Frederick County, Md., with the help of men and dogs, killed 217 large brown rats from one stack of rye.[b] In England instances are on record of the killing of over a thousand rats from one stack of wheat.

The destruction of feed by rats is a serious loss not only on the farm but also in city and village. The feed bin or barrel is often left uncovered and rats swarm to the banquet thus exposed. Small

[a] Missouri Valley Farmer, April, 1907.

[b] Am. Turf. Register, vol. 3, p. 632, August, 1832.

feeders suffer greater proportional losses, for managers of larger barns recognize the enormous drain and usually provide rat-proof bins, if not rat-proof stables. When rats have access to a stable they take a good share of the feed directly from the mangers, but the loss is seldom noticed.

Rats are exceedingly fond of malt, and in malt houses and breweries constant watchfulness is needed to prevent losses. Mills, elevators, and warehouses in which grain and feed stuffs are stored are subject to constant invasion by rats and mice.

A full-grown rat consumes about 2 ounces of grain daily. A half-grown rat eats nearly as much as an adult. Fed on grain, therefore, a rat eats from 45 to 50 pounds a year. The cost depends somewhat on the kind of grain. If wheat, the value is 60 to 75 cents; if oatmeal, about $1.80 to $2. Several feeders of horses in Washington, D. C., estimated the cost of keeping each rat on their premises at $1 a year. Even though half the grain eaten is waste, the direct loss from this source to feeders is enormous.

MERCHANDISE IN STORES AND WAREHOUSES.

The loss from depredations of rats on miscellaneous merchandise in stores, markets, and warehouses, is second only to the losses on grains. Not only are food materials of every kind subject to attack, but the destruction of dry goods, clothing, books, leather goods, and so on is equally serious. Merchandise other than foodstuffs is usually destroyed for making nests, but books and pamphlets, especially the newly bound, and some other articles, furnish food in the glue, paste, oils, or paraffin used in their manufacture. Some kinds of leather have a peculiar attraction for rats, while others are never touched. Shoes are seldom gnawed unless they have cloth uppers or are made of kid. New harnesses are not often attacked, except collars, which contain straw, and cruppers, which are stuffed with flaxseed. Old harness leather is salty from the perspiration of horses, and rats and mice gnaw it for this reason. Kid gloves and other articles made of similar leather are often destroyed by rats.

Lace curtains, silk handerkerchiefs, linens, carpets, mattings, and other dry goods in stores are often attacked by rats. Some of the stuffs contain starch, which serves as food, but most of them furnish nesting materials only. A slight injury makes these articles unsalable; this is especially true of white goods, which are easily ruined by soiling. Nearly all large dry goods and department stores suffer heavy losses from rats. Grocers, druggists, confectioners, and other merchants also have similar experiences, and to the direct losses must be added the sums expended in fighting the pests.

MERCHANDISE IN TRANSIT.

Merchandise billed for shipment often lies for days in stations and warehouses or on wharves, where depredations of rats and mice cause heavy losses to shippers and consignees. Similar losses occur on boats carrying merchandise from port to port.

Fruits and vegetables in transit on steamboats are often destroyed or damaged by rats. Tomatoes, cucumbers, sweet potatoes, bananas, oranges, grape fruit, peanuts, and similar produce shipped by water from the South, especially in winter, reach northern markets with a large percentage of loss.

In view of the practicability of destroying rats on ships by fumigation, and the ease with which rat-proof compartments for stowing produce can be constructed, it would seem that losses of this nature should be entirely prevented.

POULTRY AND EGGS.

Aside from disease, the greatest enemy of poultry is the rat. The loss from rats varies with their abundance and the care taken to exclude them from the poultry yard. The magnitude of the damage is not generally known, because much of it is blamed on other animals, particularly minks, skunks, and weasels. Much of the injury occurs at night, and the actual culprit is seldom detected. Farmers have heard that minks, skunks, and weasels prey upon poultry. What more natural than to conclude that one of these animals is doing the mischief, especially if one has been seen about the premises?

Rats often prey upon small chicks, capturing them in the nests at night or even about the coops in the daytime. The writer has known rats to take nearly all the chicks on a large poultry ranch, and over a large section of country to destroy nearly half of a season's hatching. Young ducks, turkeys, and pigeons are equally liable to attack, and when rats are numerous, are safe only in rat-proof yards.

A writer in a western agricultural journal states that in 1904 rats robbed him of an entire summer's hatching of three or four hundred chicks.[a] A correspondent of another newspaper says, "Rats destroyed enough grain and poultry on this place in one season to pay our taxes for three years."[b] When it is remembered that the poultry and eggs marketed each year in the United States have a farm value of over $600,000,000, it will be seen that a small percentage of loss represents an enormous sum.

The destruction of eggs by rats is great, not only on the farms where they are produced, but also in the markets. Commission men and grocers complain of depredations upon packed eggs. The

---

[a] Homemaker (Des Moines, Iowa), May 27, 1907.

[b] Missouri Valley Farmer, April, 1907.

animals break and eat a few eggs at the top of a case and the broken yolks run down and soil the eggs below. Then, too, rats carry away unbroken eggs, displaying much ingenuity in getting them over obstacles, as up or down a stairway.

A commission merchant in Washington, D. C., states that he once stored 100 dozen eggs in a wooden tub in his warehouse and left them for nearly two weeks. He then found that rats had gnawed a hole through the tub, just under the cover, and had carried away 71½ dozen, leaving neither pieces of shell nor stains to show that any had been broken.

Besides their destruction of eggs and young fowls, rats eat much of the food put out for poultry. They are destructive also to tame pigeons and their eggs, but particularly to young squabs. They climb the wire netting and gain entrance to the cages through the same openings by which the pigeons come and go. Fanciers are often put to great trouble to protect their pigeons from rats, and because of these pests some of them have abandoned the business.

GAME AND WILD BIRDS.

The rat is the most serious pest in European game preserves. A writer in Chambers's Journal says:

> In a closely preserved country at the end of an average year the game suffers more from the outlying rats of the lordship than from the foxes and mustelines together. The solitary rats, whether males or females, are the curse of a game country. They are most difficult to detect, for in a majority of cases their special work is supposed to be done by hedgehog, weasels, or stoat.[a]

The propagation of game birds is becoming a promising industry in the United States. The difficulties of the business are not yet fully known, but the rat is an enemy with which the raiser of game will have to contend. The animal has already proved itself a foe in American pheasantries.

Our wild native game birds are less subject to rat depredations than birds kept in confinement. The nests of ruffed grouse are in woodlands; those of the prairie hen and related species are on plains remote from the haunts of rats. The quail, however, often makes its nest within the summer range of rats, which destroy many of its eggs.

Rats are said often to destroy the nests of wild ducks, woodcock, and other marsh birds. Terns have been entirely driven from their nesting grounds in this way. In England the common tern was extirpated from the Thames marshes; and on Loggerhead Key, Tortugas Islands, off the Florida coast, rats recently nearly exterminated a colony of least terns by destroying the eggs.

---

[a] Chambers's Journal, vol. 82, p. 64, January, 1905.

The nests of many ground-nesting and other song birds are robbed by rats. Crows, jays, snakes, and skunks are blamed for most of the destruction and the actual offender seldom suspected. While the other animals named do part of the mischief, the rat is a more serious foe of song and game birds than any of these.

FRUITS AND VEGETABLES.

A well-known form of damage by rats is the destruction of fruits and vegetables in cellars and pits. Apparently no garden vegetable or common fruit is exempt from attack. But the rat does not confine its depredations to stored fruits and vegetables. It attacks ripe tomatoes, melons, cantaloupes, squashes, pumpkins, sweet corn, and many other vegetables in the field; and often the depredations are attributed to rabbits or other animals, which may or may not be concerned in the mischief.

Rats are fond of the small fruits, eating not only the fallen but climbing vines and canes to obtain the ripe grapes or berries. They eat also apples, pears, cherries, and other fruits. The brown rat, while not so expert as the black or the roof rat, readily climbs trees and obtains fruit even at the extremities of the branches.

Among tropical fruits injured by rats are oranges, bananas, figs, dates, cocoanuts, and especially the pods of cacao (*Theobroma cacao*), from which chocolate is manufactured. H. N. Riddey, writing of his experiences on the island of Fernando do Noronha, South America, mentions the destructiveness of rats in this penal colony. They climb the cocoanut palms and papaw trees to devour the fruit, and do mischief in melon patches. To lessen the evil, each convict was required to bring in a certain number of dead rats, and battues were held monthly to satisfy the requirement. Sometimes the number killed in a single hunt reached 20,000.[a]

Fruits and vegetables grown under glass are subject to injury by rats. The animals usually find entrance to greenhouses by way of openings for pipes or drains.

FLOWERS AND BULBS.

Rats attack seeds, bulbs, and the leaves, stems, and flowers of growing plants, whether in the greenhouse, propagating pits, or elsewhere. Of flowering bulbs, the tulip suffers most from rats. Hyacinths also are eaten; but, probably because they are slightly poisonous, narcissus and daffodil bulbs escape injury. Rats eat pinks, carnations, and roses, cutting the stems off clean. They denude geraniums of both flowers and leaves. They attack the choicest blooms of chrysanthemums and carnations in markets, stores, and exhibition rooms, causing heavy losses.

---

[a] Zoologist, vol. 46, p. 46, 1888.

FIRES.

Rats and mice cause many fires. Several specific instances have been reported by the fire department of the city of Washington within the past two or three years. It is likely that some of these fires are caused by rats gnawing matches. The animals are fond of paraffin, which is often used to protect match heads. They carry the matches to their nests, which are composed of paper and other combustible materials, and the conditions for a conflagration are ready. Since the heads of matches contain from 14 to 17 per cent of phosphorus, actual gnawing is not required to ignite them, but heat or friction from any cause may suffice.

Fires in mills or warehouses have sometimes been traced to the spontaneous ignition of oily or fatty rags and waste carried under floors by rats. Cotton and woolen mills are said to be peculiarly subject to fires of this kind.

Sometimes rats cause fires by gnawing through the lead pipes leading to the gas meter. Workmen or others, searching for the leak, accidentally ignite the gas. Phillips's warehouse, London, was twice badly damaged by fires originating in this way, and in several instances the sleeping inmates of houses have been in danger of asphyxiation by gas freed in this manner.

The most common way in which rats and mice cause fires is by the destruction of the covering of electric light wires under floors or in partition walls. A considerable percentage of the enormous fire losses in the United States is caused by defective insulation of wires. After wires are once in position rats are the chief agents in impairing the insulation. These animals do much mischief also by gnawing off the coverings of telephone wires. In the case of electric light wires the covering is probably used by the rats for nesting material, but frequently the paraffin in the insulation is the object of attack.

BUILDINGS AND FURNITURE.

Rats seem to be able to gnaw through almost any common material except stone, hard brick, cement, glass, and iron; neither wood nor mortar suffice to keep them out of bins or rooms. They sometimes gnaw through walls or doors in a single night. In the same way they enter chests, wardrobes, bookcases, closets, barrels, and boxes. Almost every old dwelling bears evidence of its present or former occupancy by rats. Often the depreciation of houses and furniture is largely due to marks left upon them by rats—marks that paint and varnish can not hide.

Damage to dwellings by rats is a large item. The decay of sills and floors is hastened by contact with moist soil brought up from rat burrows. Ceilings, wall decorations, and floor coverings are flooded by leaks in lead pipes or wooden tanks gnawed by rats. Bricked areas and even foundations are undermined and ruined by rats. All this is real waste and a constant drain on the resources of the country.

MISCELLANEOUS.

A few instances of miscellaneous damage by rats may be mentioned to show the great variety of mischief chargeable to the animals.

A Washington, D. C., merchant reported that at one time rats in his store destroyed 50 dozen brooms worth $2.50 a dozen. In another store, in a single night, they broke $500 worth of fine chinaware on shelves and tables. A dealer in harness reported the loss of $400 worth of collars in one season. The manager of a restaurant complained of an average loss of $30 a month in table linen ruined by rats and mice. A hotel reported the destruction of $75 worth of linen in a month.

At Mobile, Ala., in March, 1908, lost jewelry worth $400 was recovered from a rat's nest in the home of Señor Viada.

In London rats at one time killed all but 11 out of an aviary of 366 birds.

At Hamburg, Germany, Carl Hagenbeck once had to kill three young African elephants because rats had gnawed their feet, inflicting incurable wounds.

Rats often gnaw the hoofs of horses until they bleed. They kill young lambs and pigs, and have been known to gnaw holes in the bodies of very fat swine, causing death.

Like the muskrat, the brown rat often burrows into embankments and dams, causing serious breaks.

The rat is one of the greatest enemies with which the sugar planter has to contend, destroying acres of growing cane.

In rice plantations rats not only break down and destroy the growing crops, but burrow into the dikes and flood the fields at the wrong season.

On the London docks and on shipboard ivory is often badly damaged by rats. They select for attack the greenest tusks, which are the more valuable.

Mail sacks and other kinds of bagging are greatly injured by rats. The consequent loss and necessary outlay for repairs are a large item in post-office expenditures and in mills and other places where bagging is used.

About the year 1616 rats caused a two years' famine in the Bermudas. In the southern Deccan and Mahratta districts of India rats ate a large part of the scant crops of 1878 and 1879, and were regarded as in a great measure responsible for the severe famine which followed.[a] A writer in Chambers's Journal stated that the Dutch

[a] Brit. Med. Journ., p. 623, September 15, 1905.

abandoned the Isle of France (Mauritius) in 1610 because of the great abundance of rats.[a]

AMOUNT OF LOSSES CAUSED BY RATS.

The damage done by a single rat varies greatly with the circumstances. We have already stated that the cost of feeding a rat on grain varies from 60 cents to $2 a year. Assuming that much of the rat's food is waste, each rat on a farm will cause a loss of over 50 cents a year. In cities the damage by a single rat probably averages more than in the country. Hotel managers and restaurant keepers state that $5 a year is a low estimate of the loss inflicted by a rat. In making an estimate it should be remembered that the rat is to be charged not only with the food it actually consumes but also with what it destroys or pollutes and renders unfit for use.

If an accurate census of the rats in the United States were possible, and if the minimum average loss caused by a rat were known, an estimate of the total annual losses from their depredations could be made. It was on such a minimum basis that the Incorporated Society for the Destruction of Vermin arrived at their total estimate of £15,000,000 ($73,000,000) as the yearly losses from rats in Great Britain and Ireland. Three propositions were assumed: first, that in cities and villages the number of rats equals the population; second, that in the country there is at least one rat for every acre of cultivated land; third, that each rat in the kingdom inflicts a damage of at least a farthing per day. Circulars asking whether these assumptions are excessive were distributed throughout the country. From 90 to 99 per cent of the replies fully indorsed each of the assumptions.

It can readily be seen that the English basis of estimate would not apply to farm conditions in the United States, where the area in the twelve leading crops alone is over 250,000,000 acres. On a basis of a rat per acre and damage of a farthing per day the annual loss on this area would be $450,000,000, a sum much too great for serious consideration. However, in the more thickly populated parts of the country an estimate of one rat per acre would not be excessive; and it is probable that in most of our cities there are quite as many rats as people. Yet it would be unsafe, owing to our vast territory and varying conditions, to make these assumptions the basis for conclusions.

Over a year ago the writer made an attempt to investigate actual conditions, and thus arrive at an estimate of the total damage by rats in the cities of Washington and Baltimore. From the data obtained the direct annual damage in the two cities was calculated at $400,000 and $700,000, respectively. The Census Bureau in 1906 estimated

[a] Chambers's Journal, vol. 21, p. 244, 1854.

the population of these cities at 308,000 and 554,000, respectively. If the estimates of damage were correct, the average loss for each person is $1.27 a year; and, on the same basis, the 28,000,000 of urban population in the United States (census of 1900) sustains an annual direct injury of $35,000,000 from rats. This is considerably lower than on the English assumption, which would make the losses in our cities over $50,000,000.

Denmark (population 2,500,000) has an estimated rat bill of about $3,000,000 a year, or $1.20 a person. Germany (population 56,000,000) is said to sustain a loss from rats of 200,000,000 marks ($47,640,000) a year, or about 85 cents for each person. The per capita estimate for the United Kingdom is about double that made for Germany. In France the loss from rats and mice for a single year (1904) was placed at $38,500,000, or a little over a dollar for each of its 38,000,000 inhabitants. These estimates are supposed to include only direct losses, but they vary enough to show that no common basis can be assumed for all countries. With present information, therefore, any attempt to state the amount of loss from rats in the United States would be largely guesswork. Considering the population and wealth of the country, however, and the vast area over which rats are abundant, it is not unreasonable to conclude that in the United States the losses from rats amount to much more than in any of the other countries named.

INDIRECT LOSSES.

To the direct losses caused by rats must be added the cost of fighting the animals and of protecting property from them. In our larger cities a number of so-called expert rat-catchers are to be found, who operate with dogs, ferrets, traps, poisons, or other means, and who have an extensive clientage among merchants, hotel managers, and others. These pay the rat-catcher a yearly or monthly stipend to keep their premises free of rats and mice. Some of the large establishments pay $200 to $600 yearly for such service. While the agreements are seldom kept in full, the clients are usually satisfied that results warrant the expense. Even when no contractor is employed, merchants are at expense for traps, poisons, the keep of cats or dogs, and other means of fighting rats. The same is true in less degree of nearly every householder.

The cost of protecting property from rats is no small item. It increases the expense of nearly all building, but it greatly reduces direct losses from the animals. The economy of rat-proof construction is everywhere manifest, in city or country, and the necessity for it can not be too strongly emphasized.

Depreciation of property and loss of rents and custom are items not generally thought of in connection with rat damage. A few years ago the writer knew of almost an entire block of city houses that remained untenanted for several months because infested by rats. As the houses were otherwise desirable, the loss of rent to the owners was probably nearly $2,000. The presence of rats in markets, hotels, and restaurants inevitably results in loss of custom, besides the direct damage by the rodents.

From every point of view the keeping of rats is exceedingly expensive, and the sooner our population can be made to realize the enormous drain upon our resources caused by these rodents the sooner can concerted measures for their destruction be made effective.

THE RAT IN RELATION TO INTERNATIONAL SANITATION.

By Asst. Surg.-Gen., John W. Kerr,
Public Health and Marine-Hospital Service.

Rats, like man, had their origin in Asia, from which continent they have finally become disseminated throughout the world. They, too, like man, are great travelers, and therefore prey on the commerce of the ships in which they are carried. For this reason, and on account of the fact that they are subject to plague and may transmit the disease from one country to another, these animals have an influence on international policy, and their control aboard ships is an international problem.

It has been estimated that there are as many rats as there are human beings, and that each rat causes each day a loss by the destruction of material of at least half a cent.

Assuming that the rat population aboard ships is as great as the human population—and my experience gained during the fumigation of ships to kill rats convinces me that on the whole it is greater—some idea may be had of the enormous migrations of rats and the toll they exact for food from international commerce. Some idea can also be had of the danger of rats in transmitting plague when it is remembered that 51 countries have been infected with the disease since the present pandemic began in Canton, China, in 1894, and when it is known that at least 146 ships have had plague infection on board during that time.

During the International Sanitary Conference of Paris in 1903 the influence of the rat in transmitting plague was borne in mind, and the international sanitary agreement, which was signed ad referendum December 3, 1903, requires the destruction of rats aboard plague-infected ships, recommends it on ships suspected of being plague infected, and permits it on ships indemne from plague. The ship is considered indemne from plague which, although coming from an infected port, has had neither death nor case on board either before departure, during the voyage, or at the moment of arrival.

The International Sanitary Convention signed at Washington, October 14, 1905, follows the text of the Paris convention, with respect to plague, consequently embodying similar requirements and recommendations as follows:

Art. XX. *Classification of ships.*—A ship is considered as infected which has plague, cholera, or yellow fever on board, or which has presented one or more cases of plague or cholera within seven days, or a case of yellow fever at any time during the voyage.

A ship is considered as suspected on board of which there have been a case or cases of plague or cholera at the time of departure or during the voyage, but no new case within seven days; also such ships as have lain in such proximity to the infected shore as to render them liable to the access of mosquitoes.

The ship is considered indemne which, although coming from an infected port, has had neither death nor case of plague, cholera, or yellow fever on board, either before departure, during the voyage, or at the time of arrival, and which in the case of yellow fever has not lain in such proximity to the shore as to render it liable, in the opinion of the sanitary authorities, to the access of mosquitoes.

Art. XXI. Ships infected with plague are to be subjected to the following regulations:

1. Medical visit (inspection).
2. The sick are to be immediately disembarked and isolated.
3. Other persons should also be disembarked, if possible, and subjected to an observation,[a] which should not exceed five days, dating from the day of arrival.
4. Soiled linen, personal effects in use, the belongings of crew [b] and passengers which, in the opinion of the sanitary authorities are considered as infected, should be disinfected.
5. The parts of the ship which have been inhabited by those stricken with plague, and such others as, in the opinion of the sanitary authorities, are considered as infected, should be disinfected.
6. The destruction of rats on shipboard should be effected before or after the discharge of cargo, as rapidly as possible, and in all cases with a maximum delay of forty-eight hours, care being taken to avoid damage of merchandise, the vessel, and its machinery.

For ships in ballast, this operation should be performed immediately before taking on cargo.

Art. XXII. Ships suspected of plague are to be subjected to the measures which are indicated in Nos. 1, 4, and 5 of Article XXI.

Further, the crew and passengers may be subjected to observation, which should not exceed five days, dating from the arrival of the ship. During the same time the disembarkment of the crew may be forbidden, except for reasons of duty.

The destruction of rats on shipboard is recommended. This destruction is to be effected before or after the discharge of cargo, as quickly as possible, and in all cases with a maximum delay of forty-eight hours, taking care to avoid damage to merchandise, ships, and their machinery.

For ships in ballast this operation should be done, if done at all, as early as possible, and in all cases before taking on cargo.

Art. XXIII. Ships indemne from plague are to be admitted to free pratique immediately, whatever may be the nature of their bill of health.

---

[a] The word "observation" signifies isolation of passengers, either on board ship or at a sanitary station, before being given free pratique.

[b] The term "crew" is applied to persons who may make, or who have made, a part of the personnel of the vessel and of the administration thereof, including stewards, waiters, "cafedji," etc. The word is to be construed in this sense wherever employed in the present convention.

Missing Page

the bare hands, and the places where found disinfected with a germicidal solution; and the quarantine officer shall assure himself that the vessel is free of rats and vermin before granting free pratique.

Additional regulations prescribe the method of disinfection of vessels for plague, and elsewhere in this publication is given a detailed description of the measures taken aboard ships at Angel Island, one of the national quarantine stations.

Elsewhere is also given an account of the measures taken to eradicate plague from certain cities on the Pacific coast, among the measures being the systematic destruction of rodents and practical rat proofing.

In a letter dated November 21, 1908, requests were made to the Department of State for reports from certain of the more important foreign seaports as to systematic measures being practiced for the destruction of rats. As a result much valuable information has been received, and acknowledgments are due and here made to the consular officers furnishing it. The data received was abstracted and classified according to countries as follows:

RAT EXTERMINATION IN CHINESE CITIES.

Although the present pandemic of plague had its origin in Canton, China, in 1894, and the disease has been endemic there practically ever since, Consul-General Bergholz states that the provincial government of Kwangtung has made no efforts to exterminate rats.

In Amoy the local authorities have never taken measures to encourage the extermination of rats, and in the absence of assistance from the local authorities but little can be done toward effective eradication.

An outbreak of plague in Shanghai in December, 1908, was attributed to the introduction of rats by ships from plague-infected ports.[a] A plan of campaign for such an emergency had previously been formulated and was put in operation. It included collection and laboratory examinations of rats and organization of rat parties to destroy rats and render houses rat proof.

In Tientsin official efforts made to exterminate rats are on lines to suit the convenience of the particular health official. The consulate at that port states that generally on the appearance of plague, the officials pay about one-half cent for each rat brought, and as the epidemic becomes severe, as much as 2½ cents gold.

In Hongkong, the question of rats in relation to plague has been of perennial interest. While on duty in the American consulate at that port, my attention was forcibly called to the influence of rodents in the transmission of plague. In 1900 it had been the practice

[a] The Municipal Gazette, Shanghai, January 7, 1909, Health Officer's report for December, 1908.

to encourage the destruction of rats in the city, and a reward of 2 cents Mexican money was offered for each rat brought to the health department. A certain number of these rats were examined from day to day from different districts.

In August, 1901, arrangements were made by which the health department collected and examined a specified number of rats each day to try to determine in some degree the relative prevalence of plague among these animals. This practice was continued for several months, with the result that the mortality among rodents from the disease was shown to have rapidly decreased until in November practically no plague-infected rats were found.

In a discussion of the subject, furnished February 2, 1909, by Dr. W. W. Pierce, medical officer of health, through Consul-General A. P. Wilder, it is stated that in 1902 the fee for rats was raised to 5 cents, and a special staff of coolies was engaged to destroy rats. The abuses on account of these bounties were so great, however, that it was found necessary to discontinue it in 1903, but the method of trapping rats was continued.

While the total number of rats taken in 1903 was 101,047, Doctor Pierce stated in effect that on account of the prejudice against disinfection, it was practically impossible to secure the addresses where the infected rats were found. The services of the staff were continued, however, until 1908, when they were abolished because it was thought, as stated by Doctor Pierce, that results were not commensurate with the cost, and many complaints were heard. The plan of furnishing traps to all persons who applied was then introduced, and in addition, structural methods which had gone on for years were continued.

The traps were distributed through district committees consisting of the more educated natives, who were informed that with their assistance it would be possible to avoid abuses which had been practiced by the official rat-catching staff.

Doctor Pierce stated that it had been impossible under other systems to secure the addresses where infected rats were found, and in order to overcome this prejudice, several hundred receptacles were placed in different parts of the city whereby the rats could be collected. These tins were visited from day to day, and by this means it was possible to locate infected districts.

Doctor Pierce stated that the use of ordinary disinfectants in plague-infected houses had been discontinued, and that a 2 per cent mixture in water of a kerosene emulsion made by stirring warm tank oil, 85 parts added gradually to 15 parts of hot, strong solution of "sunlight" soap, was used. This solution was found to instantly kill fleas and bugs, and it has been used systematically.

In Tamatave, Madagascar, and other ports of that island no efforts were being made to exterminate rats, and the American consul reported that there were no municipal or colonial laws or regulations directing such action.

RAT EXTERMINATION IN CAPE TOWN, SOUTH AFRICA.

In a report dated January 20, 1909, Dr. A. J. Gregory, medical officer of health for the colony, states that at present no persons are solely employed on rat catching, but the sanitary staff is required to take all possible measures to reduce the rodent population. By the use of bird lime a very large number of rats have from time to time been destroyed. Doctor Gregory also refers to experiments made to determine the value of tar and funnels placed on ropes to prevent the access of rats to ships. The experiments were made to simulate actual conditions that would prevail at ships lying at docks. It was found that thickly coating a rope with fresh tar had not the slightest deterrent effect on rats passing along. Funnels of a less diameter than 20 inches were equally unsuccessful, and it was thought the experiments proved the fallacy of trusting to tarred ropes or to disks of a workable diameter being able to prevent rats from migrating in either direction between shipping and shore.

RAT EXTERMINATION IN ALEXANDRIA AND CAIRO, EGYPT.

In Alexandria, Consul D. R. Burch stated that measures for the extermination of rats were practiced; that the cost of disinfection was defrayed by the municipality, which also supplied rat traps and poison.

In Cairo rat destruction was being practiced, but it was stated that the results could not be described as encouraging.

EXTERMINATION OF RATS IN THE PORT OF CONSTANTINOPLE.

Consul-General E. H. Ozmun, at Constantinople, states that while no special measures have been taken to exterminate rats in that city, the sanitary administration of the Ottoman Empire has provided measures for the destruction of rats and mice on all vessels arriving from places contaminated with plague, and he has furnished the following copy of instructions concerning vessels which have or have not undergone disinfection in view of destroying rats and mice on board:

Article 1. Vessels coming from places contaminated with plague and which have not been disinfected either in the port of departure or in an intermediary port during voyage, for the destruction of rats and mice on board, according to the regulations of the superior council of health, shall undergo their disinfection in the lazaretto while finishing their quarantine.

Art. 2. Vessels coming from places contaminated with plague provided with a certificate stating that the forementioned disinfection has been undergone may, after their admission, work in the port but without landing on the quay.

ART. 3. Vessels proceeding from an uncontaminated Ottoman or foreign port and which are provided with the certificate mentioned in article 2 shall be free to moor at the quay if it is proved that the vessel has been disinfected within a period of forty days; if not, the vessel will operate in the port or at anchor.

Vessels in a similar case not provided with this certificate but which can prove by the journal of the vessel that they have not sailed within a period of four months to a contaminated port shall be authorized to moor at the quay.

ART. 4. Vessels mooring at the quay must be at a distance of from 1 to 2 meters (39⅓ inches to 78⅔ inches) maximum. During night they must draw up the gangways and ladders, and must leave no towline suspended without protecting it with funnels, brush wood, etc.

The vessels working in the harbor must also protect their towlines in the same manner.

It is prohibited for lighters and boats to remain attached to these vessels during the night outside of the time for working.

ART. 5. The above-mentioned vessels, mooring at the quay and on the way to an Ottoman port, shall be required after having finished the loading and discharging of cargo, to pass through the disinfection prescribed by article 1 if their certificate of disinfection mentioned by article 3 is found to be out of date, and also as long as the city of Constantinople shall be considered as contaminated.

ART. 6. Vessels coming from uncontaminated quarters, although not under any restraint, are free to go to any lazaretto in the Empire and ask to be disinfected according to article 1; the latter will work without delay so as to prevent loss of time as much as possible.

ART. 7. The expenses of disinfection are to be paid by the vessels disinfected.

ART. 8. Captains, doctors, or any officers of vessels are expected to furnish the sanitary authorities with all information asked for relating to the presence of rats and mice on board the vessel.

RAT EXTERMINATION IN RUSSIAN PORTS.

In Vladivostok, according to Consul Lester Maynard, the only efforts to exterminate rats were made by the commissary department of the army. Poisons, which had for their active principle caustic lime, were distributed but were not entirely satisfactory, as the baits were not sufficiently tempting food.

The keeping of cats had been recommended as the best method of exterminating rodents, and it had been suggested that skunks, weasels, and similar animals should not be killed, as they are the best destroyers of rats and mice.

In Riga and Libau there were no laws and regulations prescribing a systematic extermination of rats. The consul reported that only in case of plague did the sanitary authorities order a thorough destruction of rats not only on ships but also in warehouses and private dwellings. The steamship companies, however, were said to employ rat poison on their vessels, and, in addition, the ships were thoroughly disinfected by means of sulphur fumes several times a year.

In Odessa it was reported by Consul J. H. Grout that the public health officers of the port had been fully alive to the importance of exterminating rats in order to prevent plague. In 1901 a systematic extermination of rats on board vessels had been inaugurated, and in 1902 this practice was extended to include all vessels leaving the port. The agent used in this process was the burning of sulphur in specially designed iron containers. In 1902, 2,054 rats were killed in 346 vessels. In 1903, 1,038 rats were killed in 68 vessels. In 1904, 17,074 were killed in 168 vessels. In 1905, 512 rats were killed in 166 vessels. In 1906, 553 rats were killed in 188 vessels. In 1907, 1,887 rats were killed in 135 vessels; and in 1908, 1,138 rats were killed in 97 vessels.

In St. Petersburg and vicinity no consistent effort, according to the consul, had been made to exterminate rats, but at Cronstadt the port authorities had experimented with ratin.

DESTRUCTION OF RATS IN TRIESTE, AUSTRIA.

All vessels arriving at Trieste from plague-infected countries on board of which rats appeared in abnormal numbers were disinfected with sulphur in accordance with rules of the Paris convention of 1903. Consul G. M. Hotschick stated that it was a rule, whether rats were numerous or not, to disinfect every vessel every six months so as to exterminate rats on board. An exception was made in the case of the Austrian Lloyd steamships plying between Trieste and the Far East, these vessels being disinfected by the Clayton apparatus. All attempts to destroy rats along the port shore had proven fruitless, according to the consul, but in custom warehouses cats were kept, thus limiting the number of rats.

The rules applying to Trieste extended to all the ports of Austria.

DESTRUCTION OF RATS IN GENOA, ITALY.

The methods employed at Genoa for the extermination of rats found on ships were those prescribed by the ministry of the interior at Rome in accordance with the Sanitary Convention of Paris.

As stated by Consul-General J. A. Smith, the regulations place all ships arriving from plague-infected ports into three categories, as follows: Infected, suspected, and noninfected. On ships coming under the first two headings all rats must be destroyed previous to the ship being allowed to pass quarantine. Noninfected ships were subject to the same regulations only in case of an unusual mortality among rats aboard, or in case of an excessive number of them being found on board on arrival, which, in the opinion of the port medical officer, required their destruction. Sulphur was used as the agent of destruction, the gas being generated in a special apparatus. This apparatus had been installed in the ports of Naples, Genoa, Messina, Brindisi, Venice, and Asinara.

Further regulations of the ministry provided for the means to be employed in preventing rats from reaching shore.

RAT DESTRUCTION IN BARCELONA, SPAIN.

In Barcelona Vice-Consul-General Wm. Dawson, Jr., reported that the officials in charge of public health measures attached no really great importance to the destruction of rats as an effective means of preventing the spread of plague. Several attempts, however, had been made to kill rats, which invade Barcelona to an enormous extent. In his report the vice-consul further stated that bacterial cultures known as *Tifus ratoso*, and supposed to have given excellent results in Formosa, had been tried without appreciable results on wild rats. He further stated that wheat boiled in a 5 per cent solution of corrosive sublimate, dried in the air, and spread in sewers and other places, had proved the most effective means of killing a few thousand of them, but this practice had not been carried out to any great extent nor for any length of time.

RAT DESTRUCTION AT FRENCH PORTS.

In Marseille the following was the practice as reported by the director of the maritime health service at that port and forwarded by Consul-General H. L. Washington:

The obligatory destruction of rats in all French ports is enforced by virtue of a decree dated May 4, 1906. This applies: (1) To all vessels arriving from a port regarded as contaminated by plague or having only touched at such port. (2) To all vessels having received in transshipment—that is to say, from ship to ship—merchandise originating in a country deemed contaminated by plague. The destruction of these animals is carried out exclusively by means of apparatus whose efficacy has been recognized by the Superior Council of Hygiene of France.

The devices employed at Marseille are:

(1) The "Marot," adopted June 19, 1905. This apparatus utilizes liquid sulphurous anhydrite, which is slackened, diluted in the air, and subjected or not to the action of the electric spark. The gas is introduced into the vessel by means of a ventilator at a rate of from 25 to 30 meters per minute (82.02 to 98.42 feet).

(2) The "Gauthier-Deglos," adopted February 18, 1907. This method requires the combustion in an oven of a mixture of sulphur and coal dust. A ventilator withdraws air from the vessel and causes it to pass over the mixture in combustion; the gas thus produced is cooled and then introduced into the vessel. A third device, known as the "Clayton," in use in some of the French ports, also operates from time to time in Marseille on such vessels as are provided with it, but it does not exist in the port itself. The principle of this device is based upon the combustion of sulphur, its transformation into sulphurous sulphuric gas, the cooling of the gases leaving the oven, aspiration of the exterior air or the air in the holds of vessels, and introduction into the holds by means of a powerful ventilator.

With all three systems, the ships' holds are opened only after they have been in operation for three hours.

In Bordeaux, according to the consul, contracts had been entered into between the Government and a private individual for the extermination of rats on all ships coming from plague-infected ports, the apparatus employed being that in use at Marseille.

In Havre the extermination of rats on vessels from plague-infected ports was reported by Consul A. Gaulin as being systematically carried out in accordance with a ministerial decree of May 4, 1906, which is as follows:

Article 1.—The destruction of rats, or "deratization," effected exclusively by means of apparatus the efficiency of which has been recognized by the Superior Council of Public Hygiene of France, is obligatory for admission into French ports:

1. Of every ship coming from or having called at a port considered as being contaminated with plague.

2. Of every vessel having taken in transshipment—that is to say, from one vessel to the other—more than 50 tons of merchandise coming directly from a country considered as being contaminated by the plague.

The above provisions are applicable to vessels having already discharged a part of their cargo in one or several foreign ports.

Art. 2.—May be exempt from deratization:

1. Vessels which only land passengers in French ports without docking and which sojourn only several hours.

2. Vessels making a call of less than twelve hours and discharging less than 500 tons of merchandise, on condition that the surveillance of discharging be accomplished during the day exclusively, the ship being moored away from the quays, and the hawsers provided with rat guards.

3. Steamships which shall not have called at any port considered as being contaminated by the plague for sixty days since their departure from the last contaminated port, and on board of which there shall have been observed nothing of a suspicious sanitary nature.

4. Vessels which, having called at a port considered as being contaminated by the plague, will prove that they neither berthed alongside the quay or landing stages, nor embarked merchandise.

5. Vessels which have undergone the process of deratization in a foreign port subsequent to their departure from the last port considered as being contaminated. It must be proven, in this case, that nothing of a suspicious sanitary nature has taken place on board during the voyage, and that the deratization has been effected with the same apparatus and the same guarantees as in France. The captain of the vessel shall deliver as proof to the sanitary authorities a certificate mentioning the apparatus employed, the conditions under which the operation was effected, the verifications made, etc., and a certificate viséed by a French consular officer.

6. Vessels whose status is that indicated in paragraph 2 of article 1, on condition that the merchandise has been transshipped from a vessel which has been deratized under the conditions prescribed in the preceding paragraph, and if such merchandise is accompanied by a certificate of deratization provided for in said paragraph.

Art. 3.—Shall be considered as merchandise, for the application of the present decree, all products embarked, figuring or not figuring on the manifest, the only exception being coal embarked for the needs of the ship without touching the quay.

Art. 4.—Deratization may be effected during the voyage by any French ship having a surgeon, and one of the machines prescribed by article 1.

The sanitary official at the port of arrival shall determine, upon examining the documents presented and the proofs furnished, the conditions under which the operation has been effected, and he may exact a total or partial renewal of the same.

The same provisions are applicable to foreign vessels, by virtue of reciprocity, on the twofold condition that the sanitary officials of the one (nation) enjoy the same standing as French sanitary officials, and that the apparatus used are the same as those mentioned in article 1.

Art. 5.—In ports, the deratization is effected before the unloading of the ship.

The operation comprises the holds, bunkers, storerooms, crew's quarters, emigrants' quarters or compartments for third and fourth class passengers, and, in general, all interior compartments of the ship.

The officers' cabins, and those of first and second class passengers, as well as the dining rooms, and saloons which are provided for them, are not subjected to deratization except in cases where the sanitary official judges it necessary—notably when the ship is suspected of being or is infected by plague, when it has been observed that the malady exists among the rats on board, or when there has been a death from unusual causes.

Art. 6.—The apparatus to be employed for the deratization, by virtue of article 1, are placed at the disposal of the owners or agents, according to the conditions approved by the sanitary authority.

Ports possessing one of these machines are alone open to vessels coming from countries considered as being contaminated by plague.

The operations are effected under the permanent supervision of the sanitary authority and with the least possible delay.

Art. 7.—The expenses of deratization are borne by the owners, in conformity with the provisions of article 94 (last paragraph) of the decree of January 4, 1896. No sanitary tax is due, in consequence, for the operation.

Art. 8.—The expenses considered in article 7 are based on the gross tonnage of the ship, if the deratization comprises all its parts, and on the cubic capacity of the parts deratized, if the operation is partial. The cubic capacity is determined by and from the plans of the ship, without allowing for the space actually occupied by merchandise.

Art. 9.—A certificate setting forth the conditions under which the operation has been effected is delivered to the captain or owners by the sanitary authority.

Art. 10.—Ships which are not necessarily subject to the requirements of deratization may, upon their request, be subjected to this operation upon their departure, as on their arrival, either with full or empty holds, and obtain, in consequence, the delivery of the certificate mentioned in article 9. Every facility should be accorded them for this purpose.

Art. 11.—Violations of the provisions of the present decree are punishable by the penalties set forth in article 14 of the law of March 3, 1822, independently of the measures taken for the isolation or other measures to which ships are subjected by reason of their origin or the sanitary condition on board at the time of arrival.

Art. 12.—Are annulled, the decree of September 21, 1903, and the provisions of the decree of September 23, 1900, which would be at variance with the second paragraph of article 6 above cited.

Art. 13.—The minister of the interior is charged with the execution of the present decree, which shall be published in the Official Journal, inserted in the Bulletin of Laws, and posted in the ports.

DESTRUCTION OF RATS IN GERMAN PORTS.

In Hamburg, according to Consul-General R. P. Skinner, stationed at that port, persistent efforts were being made to exterminate rats not only on board ship but in the city itself, and he reported the following method of procedure:

Upon the arrival of every vessel an inspecting officer employed by the board of health boards the same to inquire whether, during the voyage, rats have died in exceptionally large numbers. While in port the vessel is visited almost daily by inspectors, who search for dead rats, particularly in the holds. On vessels from such ports whence plague-infected rats have been brought to Hamburg repeatedly an officer of the board of health is posted on board constantly to watch the discharging of the cargo. All dead rats found are immediately delivered to the Hygienic Institute; and if the latter's bacteriological examinations give reason to suspect plague, the discharging is immediately discontinued and communication with the shore interrupted. The vessel's crew and discharging gangs are placed under medical observation for a period of five days, the cargo compartments are treated with generator gas, so as to exterminate all rats, and, after the quarantine has been discontinued and the cargo discharged, all compartments are carefully disinfected. For the purpose of treating infected ships by means of generator gas the Hamburg government owns a special disinfection ship, called the *Desinfektor*, which will be described later.

In order to exterminate rats on ships frequenting the port of Hamburg the master of every vessel arriving here receives the following instructions from a representative of the health officer of the port:

He shall cause rat poison to be laid and fumigate holds by means of sulphur and charcoal as soon as the cargo has been discharged, not less than 10 kilos (22 pounds) of sulphur and 20 kilos (44 pounds) of charcoal to be used for a room of 1,000 cubic meters (1,308 cubic yards). Such rooms must be kept closed at least ten hours. On ships arriving from ports infected with plague, rat poison is laid, free of charge, immediately upon arrival, by an employee of the municipal disinfection establishment, at all places within reach. On all other ships the laying of rat poison is done by private persons whose charges are payable by the vessel's master or owner.

The disinfectors employed by the State of Hamburg use principally a rat poison called "Rattengiftspeise," consisting chiefly of phosphorus and squills. Private rat killers may choose any other material, but from time to time samples of such poisons as are laid out on ships are taken by order of the harbor surgeon, and rats kept in the public laboratories are fed with them, to enable a control as to the effectiveness of the poison.

Under special circumstances the harbor surgeon is authorized to waive the requirement of fumigation.

Killed rats are not permitted to be thrown overboard, but must be delivered to the nearest police station, which causes their cremation.

On river barges rat poison is laid by official disinfectors every three months.

Finally there is rat poison laid, from time to time, in warehouses, cargo sheds, and trade establishments in the harbor, partly by official disinfectors and partly by private rat killers, which is regularly controlled by the harbor surgeon, a special officer of his department being engaged for such purpose.

The ship called the *Desinfektor*, owned by the government of Hamburg for the purpose of disinfecting ships arriving from infected ports and for the extermination of plague infected rats, is a steamer equipped with a generator gas apparatus and other disinfecting facilities. The method of using generator gas has been chosen for reasons which are described in a booklet issued some time ago by the local board of health on this subject.

In respect to the extermination of rats in Hamburg, aside from the system adopted for ships and in the harbor, the consul-general states that efforts to this end are being successfully carried out by official disinfectors by order of the board of health, and he refers to the procedures as follows:

If it becomes known to the board of health that in any locality or group of buildings there are rats in large quantities, rat poison is immediately laid. For such purpose the above-mentioned Jungclaussen's preparation is almost exclusively used. The several local citizens' associations (Bürgervereine), at the meetings of which all topics of interest are discussed, contribute largely to the bringing to the knowledge of the proper authorities of all matters a remedy of which is, in public interest, considered necessary, among them rat and mice nuisances in the several districts of the city. Of late the board of health has also begun to lay rat poison in houses in the old parts of the city, employing the house-to-house method, and rat poison is laid, from time to time in sewers and other underground canals where rats usually congregate in large numbers.

As the laying of rat poison at or in the vicinity of places where domestic animals are kept is dangerous to the latter, the Hamburg board of health has only shortly ago caused a small gas generator to be constructed, similar to that on the *Desinfektor*. The apparatus can easily be removed from one place to another, and is chiefly to be used on yards or unimproved lots, public parks, zoölogical gardens, etc., where rats live under the ground. In fumigating such a rat nest, all holes leading out of it are closed with earth, except two. The hose of the gas apparatus is introduced into one of the holes and gas insufflated. The majority of rats in the hole are dead before being able to reach the fresh air. Those succeeding in doing so, by getting out of the one open hole, are so dizzy that they can easily be killed with a club. Only a few experiments have so far been made with this apparatus, but the same promises good success.

In Bremen, according to the consul, all disinfection of vessels and their cargoes was done with sulphur dioxide by means of a Clayton apparatus, and vessels equipped with this apparatus, and those having physicians aboard, had the advantage of being able to start disinfection twenty-four hours before arrival at port, this process having been recognized as sufficient compliance with the quarantine laws of Germany.

MEASURES AGAINST RATS AT THE PORT OF ROTTERDAM.

In the report from Consul-General S. Listoe it was stated that the extermination of rats had not been officially undertaken by the authorities of Rotterdam, either in the port or aboard incoming ships. The question had been investigated, however, and the harbor master had strongly advised the installation of a fumigating machine, which would be installed on one of the numerous river police boats. Ship owners had, for their own protection, caused their ships to be occasionally fumigated, and two of the well-known lines had fitted out some of their steamers with fumigating apparatus.

DESTRUCTION OF RATS AT ANTWERP, BELGIUM.

Consul-General H. W. Diedrich stated that no official action had been taken in the port of Antwerp for the extermination of rats, but that every vessel entering the port had to pass the sanitary station at Doel, and there was authority to hold up any suspected vessel and to insist on fumigation for the destruction of rats.

DESTRUCTION OF RATS IN DENMARK.

As a result of the agitation started in 1898, the following law was passed and signed by the King of Denmark on March 22, 1907:

1. When an association constituted for the purpose of effecting the systematic destruction of rats has proved to the satisfaction of the minister of the interior that it is in a position to expend on the furtherance of its objects, within a period of three

years, a sum of not less than 10,000 kroner per annum, it shall become incumbent upon each local authority to make suitable arrangements at the expense of the local funds, and commencing with a date to be made known hereafter by the minister of the interior, for the reception and the destruction of all rats killed within the district of such authority and delivered up to such authority.

For each rat delivered up each local authority shall pay a premium, for the payment of which an annual grant shall be made out of the local funds, which shall be not less than three kroner per each hundred inhabitants within the district of each local authority, according to the then last general census.

The State shall make for a period of three years an annual grant of 30,000 kroner, of which one-third may be expended on scientific experiments with preparations for the extermination of rats, under the control of, and in consultation with, the Royal Veterinary and Agricultural College, while the remainder shall be expended on purchasing preparations for the extermination of rats, which shall be either employed on or in public lands or buildings, or out of which remainder grants may be made to associations toward the purchase of such preparations, in a manner to be defined hereafter by the minister of the interior.

2. Each local authority shall fix the amount of the premium (sec. 1) which shall not, however, be more than 10 oere or less than 5 oere.

Instructions for the collection and destruction of the rats killed will be issued by the minister of the interior.

3. The association cited in section 1 shall submit for the sanction by the minister of the interior at the beginning of each year a plan showing the proposed expenditure, and at the end of each year an account of the money expended by it, together with statistics obtained by it showing the expenditure on premiums made by each local authority.

4. Where the proprietor or occupier of a messuage has participated in the grant to be made by the State (sec. 1), he shall not deliver up, or cause to be delivered up, for the purpose of obtaining a premium or premiums, rats killed within the said messuage, until the expiration of one month from the employment of such preparation for which such grant has been made. Any person acting in contravention of this section shall be liable to a penalty of 100 to 500 kroner.

5. Any person who preserves or breeds rats or imports rats from abroad, in order to obtain premiums or enable another person to obtain them, shall be liable to a penalty of 100 to 500 kroner, unless he is liable to a higher penalty under the common law. A person who shall deliver up rats knowing them to have been preserved, bred, or imported for the purpose of obtaining a premium shall be liable to the same penalties.

All proceedings under this act shall be taken in a public police court, the fines to go to the special funds provided by this act, or where such fund does not exist, to the public funds of such local authority.

Any person delivering up rats to any other local authority than to that within the district of which they have been caught shall be liable to a penalty not exceeding 100 kroner.

This act shall come into operation on a date to be fixed hereafter by the minister of the interior and remain in operation for three years.

In the session of the Riksdag immediately preceding the expiration of this law a vote shall be taken for the renewal or revision of this law.

The Government is authorized by royal rescript to make such alterations in the operations of this law within the Faroe Islands as may be considered most suitable, having regard to the special conditions obtaining within those islands.

Following the enactment of this law, there was issued by the ministry of the interior May 1, 1907, a circular to the local authorities on the subject.

CIRCULAR TO THE LOCAL AUTHORITIES.

Whereas the Association for the Authorized Extermination of Rats has proved to the satisfaction of the ministry of the interior that it is in a position to expend on the furtherance of its objects not less than 10,000 kroner within a period of three years, it is hereby requested, in pursuance of act No. 59, of the 22d March, 1907 (see public notice dated this day), and commencing with the 1st day of July of this year each local authority shall at its own expense take all such measures as may be necessary for the reception and destruction of all rats killed within the district of such authority and delivered up to it. For the purpose of paying a premium for each rat delivered up each local authority shall out of the common funds make an annual grant which shall be not less than 3 kroner for each hundred inhabitants, according to the then last general census; should the amount required for the payment of premiums make such grant necessary. It shall be left to each local authority to decide whether further grants shall be made toward this purpose. The premium to be paid for each rat delivered up shall not be more than 10 oere or less than 5 oere, and shall be fixed by each local authority which shall give due and sufficient notice both of the date fixed for the commencement of the operations of the law and the premium to be paid. As far as possible, a uniform rate of payment by premium shall be fixed by local authorities within the same county. Rats may not be delivered up to any local authority but to that within the district of which they have been caught; any person acting in contravention (par. 5 of the aforementioned law) shall be liable to a penalty not exceeding 100 kroner.

The chairman of the councils of the various local authorities are hereby requested to take steps for the discussion and carrying out of the provisions of this law.

If the grant made by any local authority for the purposes of this law should prove insufficient for the payment of premiums on all rats delivered up, such authority may apply to the Association for the Authorized Extermination of Rats, Colbjoernsengade 14, Copenhagen B, for a subsidy, this association having undertaken to organize the obtaining of voluntary subscriptions for the carrying out of the purposes of this act.

The said association is further prepared, at the request of local authorities, to render expert assistance in commencing and carrying through operations under this act.

For the collection and destruction of rats killed the ministry of the interior issues the following instructions:

A.—THE LARGER TOWNS.

Collecting depots.—The local authorities shall provide a sufficient number of places suitable for collecting depots. Such depots must not be within any place where food or clothing is made or offered for sale. Fire brigade stations are considered most suitable for collecting depots.

The collecting may suitably be done in the manner that for each depot a number of receptacles are provided, made of galvanized iron and furnished with a tight-fitting lid. Into these receptacles the rats are to be thrown after their tails have been cut off. The tails are to be kept in a separate tin box. All receptacles and boxes are to be collected daily and to be replaced by empty receptacles. The full receptacles are to be taken to the place where the destruction of the rats is effected.

Further advice on the purchase of such receptacles and the apparatus for cutting off their tails will be given by the Association for the Authorized Extermination of Rats at the request of a local authority.

The destruction may be effected either by cremating the dead rats—for instance, at the municipal gas works—or by burying the carcasses in the open, at a sufficient distance from the town, unless this course is prohibited by local sanitary considerations. It is recommended that the local authority act in this manner always with the local health committee.

B.—THE SMALLER TOWNS.

Instead of opening a fixed depot, it would appear more suitable in the smaller towns to provide a collecting cart. Any horse-drawn vehicle would serve the purpose as long at it is furnished with a fixed apparatus for cutting off the tails and a receptacle of galvanized iron for receiving the carcasses of the rats. The vehicle should also be fitted with a bell, to announce the arrival and presence of the collecting cart.

The destruction of the carcasses is to be effected in the manner described under A.

C.—THE VILLAGES.

The authorities in the villages shall appoint a suitable person to receive the rats delivered up, for which work he shall be paid an adequate remuneration. Such persons must be supplied with an apparatus for cutting off the tails of rats handed in. After the tails have been cut off, the rats may be buried in a suitable place without delay. It is most undesirable that any person engaged in the carrying of milk or other foodstuffs be asked to convey rats to the persons appointed to receive them. Villages in close proximity to towns are advised to make arrangements for the cremation of the rats at the municipal gas works.

In the case of villages whose buildings approximate those of a town it is recommended that the regulations given for towns are adopted.

Respecting the payment of the premiums it is recommended that the person in charge of a collecting depot or otherwise appointed to receive rats is supplied with a fixed amount of petty cash, out of which he pays the premium for each rat delivered up. The tails cut from the rats serve as a receipt for the payment made, so that the total amount of tails will be a discharge for the total amount of petty cash received and paid out in premiums.

In order to prevent abuse it is particularly requested that the local authorities take care that the rat tails are destroyed in an efficient manner as soon as they have served the purpose of control and checking.

For the purpose of keeping satisfactory accounts the Association for the Authorized Extermination of Rats has on sale specially arranged account books which are recommended by the ministry of the interior.

As in accordance with paragraph 3 of the law of 22d March, 1907, it is the duty of the Association for the Authorized Extermination of Rats to submit to the ministry of the interior a report on the money expended in the whole of the kingdom on such premiums, the local authorities are hereby desired to make a quarterly return to the aforementioned association on the number of rats killed within the district of each authority in each month of the quarter covered by such return and on the money paid out for premiums. Forms for such returns will be supplied by the association.

Any associations which in accordance with terms of paragraph 1 of the law of 22d March, 1907, desire to participate in the grant made by the State for the purpose of purchasing preparations for the extermination of rats (ratin, etc.) must send a request to that effect to the minister of the interior, together with a statement showing the approximate cost of the proposed campaign and the amount at the disposal of the association for that purpose. As this law is essentially of an experimental character, the requests of all such associations will be treated as preferential, which show that the proposed extermination may be easily and successfully effected (as, for instance, on small islands).

A number of copies of this circular will be forwarded to each local authority.

DESTRUCTION OF RATS IN SWEDISH PORTS.

Consul W. H. Robertson at Gothenburg, Sweden, quoted the city physician to the effect that "upon the appearance of plague in Great Britain the city council decided in April and November, 1901, to make an appropriation of $2,680 for an attempt to reduce the number of rats within the community." These attempts were continued during the period May, 1901, to September, 1902, 2.68 cents being paid for each rat caught. Any unusual mortality among rats on board a vessel coming from a plague-infected port was being dealt with in accordance with a royal proclamation of June 16, 1905.

In Malmo, according to the consular agent, the authorities during the past seven years had given a premium for every rat killed during the first five years, 2.68 cents for each rat, but during the past two years only half of that amount.

DESTRUCTION OF RATS IN ENGLISH PORTS.

The Local Government Board has issued regulations for the prevention of plague and certain other diseases. One of these regulations is as follows:

> The master of a ship which by reason of plague is an infected ship, or a suspected ship, or which has come from, or has during the voyage called at, a port infected with plague, or in which there are rats infected with plague, or in which there is or has been during the voyage an unusual mortality among rats, shall, under the direction and to the satisfaction of the medical officer of health, take all such precautions or employ all such means for effectually stopping the access of rats from the ship to the shore as in the opinion of the medical officer of health are measures reasonably necessary for the prevention of danger arising to public health from the ship.

In accordance with this regulation, notice was given in a circular issued by the medical officer of health of the port of London of the precautions necessary for stopping the access of rats from ship to shore in that port. These precautions were outlined as follows:

1. All ropes and mooring tackle for securing the vessel either to the shore or mooring buoys shall be fitted with metal brushes, funnels, or other effective guards, the portions of such ropes and mooring tackle leading from the vessel to a distance from the vessel's side of at least 4 feet shall be coated each night with fresh tar. Ropes may, if desired, be protected by a covering of canvas or yarns before tarring.
2. When not engaged in discharging cargo, one gangway only shall be permitted to afford means of communication between the ship and the shore.
3. The end of the gangway near the ship shall be whitened for a length of 10 feet, and the watchman shall keep the gangway pulled inboard after sunset, or it shall be guarded in some approved manner.
4. When alongside the quay, the ports on the side of the vessel nearest the quay shall be kept closed after sunset.
5. All empty cases and barrels, especially those from the storerooms, shall be examined before being landed, to insure that no rats are contained therein.
6. It is recommended that all possible means be adopted for catching and destroying rats, both on the voyage and during the stay of the vessel in port. Any rats so caught shall be killed, then placed in a bucket of strong disinfecting solution, and afterwards burnt in the ship's furnace.
7. No rats, alive or dead, are to be removed from the ship without my permission in writing.

In London, the practice of destroying rats on the docks had been systematically carried out by the dock companies at their own expense and under the supervision of the port sanitary authority. Vice-consul Richard Westacott reported that the destruction of rats on vessels was provided for by regulation whenever the medical officer of health was satisfied that such precaution against the introduction of the spread of plague was necessary.

In Liverpool, Consul J. L. Griffiths stated that earnest endeavors were made to capture rats by professional rat catchers. On infected or suspected ships, special precautions were taken to prevent the escape to the shore of rodents. On noninfected or nonsuspected ships the medical officer of health might also require the destruction of rats, and in this case the expense was borne by the sanitary authority. It is evident, therefore, that the precautions taken are in accordance with the provisions of the International Sanitary Convention of Paris.

It was the practice, at the time the consul sent his dispatch, to maintain strict surveillance over vessels likely to develop plague aboard until after the period of incubation had been passed.

In Southampton, according to Consul A. W. Swalm, a competent man was employed by the dock authorities whose sole duty was to wage war on rats. In addition, the night watchmen on all vessels were required to perform the additional duty of trapping rats. The usual precautions to prevent the passage of rats from ship to shore were also observed.

MEASURES AGAINST RATS AT AUSTRALIAN PORTS.

The following are the regulations issued under the quarantine act of 1908 by the commonwealth of Australia relating to the ingress to and egress from vessels of rats and mice; the destruction of rats, mice, and other vermin; and precautions against the introduction of vermin from plague-infested places.

136. (1) The master or owner of every vessel shall—

(*a*) Effectively obstruct—against the migration of rats—by means of stout wire netting, all pipes, ports, cabin scuttles, and other openings or holes in the side of the vessel next to the wharf, and also when cargo is being discharged into lighters, in the side next to the lighters, and keep them so obstructed while the vessel is alongside the wharf or lighters;

(*b*) Prevent any organic refuse, galley scraps and waste from being discharged into the waters or on the wharfs of any port.

(2) The master or owner of any vessel arriving in any port in Australia from any place proclaimed infected with plague, or as a place from or through which plague may be brought or carried, under section 12 of the quarantine act, 1908, shall—

(*a*) Produce to the quarantine officer a certificate showing that an efficient fumigation of such vessel while empty had been carried out prior to departure. Such certificate, in the case of an oversea vessel, must (if the port of departure be within the British dominions) be signed by the health officer of the port; or, when such port is a foreign port, by the British consul. In the case of an interstate vessel the certificate must be signed by a quarantine officer. In the absence of such certificate the quarantine officer may require the cargo to be discharged in the stream. Efficient fumigation in this regulation shall mean fumigation as specified in regulation 137 (2) *b*;

(*b*) Suspend or cause to be suspended over the side of the vessel against the wharf, or against any lighter alongside, electric or other effective lights, distributed so as to afford from sunset to sunrise thorough illumination fore and aft along the whole side of the vessel.

137. (1) The owner or master of any vessel shall—

(*a*) Keep all foodstuffs and food refuse in rat-proof and mouse-proof receptacles;

(*b*) Thoroughly flush out and afterwards empty the bilges before berthing at any port;

(*c*) Keep on board the vessel a dog or a cat—or both—efficient for rat and mouse killing, and give it or them constant access to those parts of the vessel where rats or mice may harbor;

(*d*) Set and keep set in sufficient numbers and in suitable places metal break-back traps or other effective traps for rats and mice; and

(2) When so ordered by a quarantine officer, shall—

(*a*) Lay on the vessel poison baits effective for rats and mice;

(*b*) Submit the holds and other such parts of the vessel as the quarantine officer directs to sulphur fumigation in accordance with this regulation, or to some other method of fumigation approved by the director of quarantine. Sulphur fumigation shall be effected by passing sulphur fumes into the vessel under pressure, and at the same time exhausting the air in the parts of the vessel under fumigation, and shall be continued until all parts of the vessel under fumigation are filled with a gaseous mixture of a strength of not less than 3 per cent of sulphur oxides, and are kept so filled for at least eight hours.

The fumigation shall, if the quarantine officer so orders, be carried out in the stream or away from a wharf.

(*c*) Clean, wash, or spray all portions of the vessel likely to harbor or afford shelter to vermin, with an approved insecticidal solution effective for the killing of fleas, lice, bugs, and other vermin; and

(*d*) Flush, cleanse, disinfect, or empty all lavatories, water tanks, or any closed-in space on board the vessel, and cause to be produced for disinfection any articles desired by the quarantine officer.

In Sydney, it was stated by the president of the department of public health that steady, systematic poisoning and trapping of rats were done all the year round, and that this had been the case for the past eight years. The experience there had been that mineral poisons were found to answer best, and that organic viruses had been found to be not practically successful.

In Melbourne, rat destruction was carried on by the board of public health of Victoria and by the local health authorities under the Victorian health act of 1890. As stated in the report of Consul J. M. Jewell, the board of public health restricts its operations to shipping wharves, to shores, and banks of the River Yarra upon which Melbourne is situated. Since 1900, the board had had a staff of men continually engaged in distributing poison baits. In order to prevent the passage of rats to and from vessels, certain specific berthing restrictions were in force. In addition, fumigation of vessels was practiced under the supervision of the board's officers. The board had continually urged the various municipal authorities to maintain the crusade against rats and render dwellings rat proof.

The consul also stated that the local municipal councils paid a bonus for every rat, and that the fee was then 4 cents.

In Adelaide, it was stated there were no compulsory regulations for the destruction of rats, but shipping companies had cooperated with the local sanitary authorities to keep down these rodents on the wharves by means of poison and traps, the poison being supplied gratis by the board of health.

In Fremantle, and other seaports of Western Australia, according to the consul-general, men were engaged in baiting and trapping rats, these precautions being maintained throughout the year.

MEASURES AGAINST RATS IN SOUTH AMERICAN PORTS.

In Buenos Aires it was stated by the chief of the asistencia publica that a regular staff of 150 men was employed in the destruction of rats and fumigation of houses. A map of the city showing houses that had been found to contain rats was marked. In addition, a pesthouse was maintained in which live rats were watched, and developments of pest noted.

In Montevideo Consul F. W. Goding stated that there were no organized efforts for the destruction of rats, but that vessels were fumigated at stated intervals under the direction of the sanitary authorities. He also stated that the Government had required portions of the sea wall to be covered with cement in order to prevent rats obtaining a lodging there.

In Callao, Peru, provision was made for the fumigation of vessels from infected ports, and it is stated by Consul-General S. M. Taylor that the Government had required steamship companies to install fumigating apparatus on board their passenger vessels.

It is stated by the consul that there was a new municipal law in Callao calling for stone or brick 2 feet below and 2 feet above ground on all walls and foundations for new buildings, and concrete floors in all establishments where provisions are sold.

In Iquique, Chile, it was reported by the consul that the director of the municipal laboratory disinfected houses infected with plague, and sent a corps of men to poison and trap rats which might be therein.

MEASURES AGAINST RATS IN WEST INDIAN PORTS.

From Habana it was reported that no action had been taken by the sanitary authorities toward exterminating vermin, except the promulgation of a circular letter calling attention to the presence of the plague in neighboring countries, and requesting citizens to free their premises of rats. The same statement was also said to apply to other Cuban seaports.

In Kingston, Jamaica, on account of the appearance of the plague in Venezuela, the government took precautionary measures with the view of exterminating rats. These steps, as reported by Vice-Consul W. H. Orritt, were as follows:

A. Lectures were delivered in various centers of the island showing how rats are the distributers of plague and the necessity of destroying them.

B. Virus was imported, and live rats were inoculated and set free in every seaport in the island.

C. Bamboo pots with poison glued to their bottoms were distributed to householders and placed in the haunts of rodents.

In Santo Domingo bounties for rats were authorized May 19, 1908, by the city council. In addition, rat virus had been used in considerable quantity.

DESTRUCTION OF RATS IN PANAMA.

In Cristobal, Canal Zone, Colon, and Bocas del Toro, it was stated by Consul J. A. Kellogg that the sanitary department of the Isthmian Canal Commission had for some time been exterminating rats by traps and poisons.

In La Boca, Canal Zone, Consul-General Arnold Shanklin stated that the sanitary department of the Isthmian Canal Commission and the Public Health and Marine-Hospital Service had in charge and had most effectually carried on the extermination of rats, and that this crusade had also been extended to the old docks and wharves in the city of Panama.

MEASURES AGAINST RATS IN VANCOUVER.

It was stated by Consul-General George M. West, December 17, 1908, that the city of Vancouver was paying a bounty of 50 cents per hundred for all rats caught. The following regulations for the docking or mooring of vessels arriving from plague-infected ports became effective April 8, 1908:

1. All vessels arriving at British Columbian ports from ports infected or suspected of being infected with bubonic plague shall conform to the following regulations:

(*a*) Vessels shall be moored or docked at a distance not less than 6 feet from wharf or land.

(*b*) Ropes or chains connecting a vessel with wharf or land shall be protected by funnels of size and shape satisfactory to local and provincial boards of health.

(*c*) All gangways shall be lifted when not in use. Gangways when in use shall be guarded against the exit of rats by a person specially detailed for this purpose.

(*d*) All vessels changing route to solely British Columbian ports shall give satisfactory evidence of disinfection and extermination of vermin to provincial board of health.

2. Every owner, agent, or captain of any vessel, and every other person violating or instructing, authorizing, ordering, permitting, or otherwise suffering any person to violate any of the foregoing regulations, shall be liable, upon summary conviction before any two justices of the peace, for every such offense to a fine not exceeding $100, with or without costs, or to imprisonment, with or without hard labor, for a term not exceeding six months, or to both fine and imprisonment, in the discretion of the convicting magistrates.

Dated at Victoria, 8th April, 1908.

In addition, the mayor and council of the city enacted a by-law November 11, 1907, one provision of which made it unlawful for any boat entering the port of Vancouver to be connected with any wharf in the city by a gangway which was not guarded by some person there for the purpose of preventing rats from leaving such port by such gangway.

NECESSITY OF CONCERTED ACTION OF NATIONS.

It appears from the foregoing data that a more or less widespread crusade against rats is being carried on in the different ports of the world, and that the extent and persistence of these measures, with few exceptions, depend upon whether the particular port has been directly threatened with an invasion of plague. It is necessary to state here that the above data are not presented as a complete epitome of measures taken throughout the world, but refer to the ports from which consular reports were received.

The fact that within fifteen years plague has spread to no less than 52 countries indicates that the measures taken against rats have not been wholly efficient.

It is too much to expect that the rat population can ever be exterminated from any country, but by the adoption of systematic measures, such as are in force in Denmark, the rat population should be markedly reduced, and the occurrence of plague among rodents quickly detected. It is not too much to expect, however, that ocean carriers could be freed from rodents and kept so, and this action would confine plague within continental boundaries.

When the existing sanitary conventions were adopted several years since, the importance of the subject was just beginning to be recognized, but now that the rat has been proven beyond all doubt to be the greatest factor in the transmission of plague from one country to another it would appear that the conventions in question should be amended, and the Surgeon-General of the Public Health and Marine-Hospital Service, in a communication of February 26, 1909, addressed to the Secretary of State, suggested the advisability of submitting the question of the systematic destruction of rodents aboard ships to an international sanitary conference with the view to the adoption of an international sanitary regulation on the subject.

It must be apparent that such a regulation would lessen quarantine restrictions, prevent the destruction of cargo by rodents, and in large measure obviate the danger of the further spread of plague.

O