where the relative humidity is above 35 percent.

The flea population, and the danger as well, is greatest in moist, warm climates; rat-flea cases have occurred in Honolulu, T. H.; Seattle, Wash.; San Francisco, Berkeley, and Los Angeles, Calif.; Galveston and Beaumont, Tex.; New Orleans, La., and Pensacola, Fla., and in Puerto Rico (table 1). Infected domestic rats also have been found in Tacoma, Wash.; in Ventura, Marin, and Contra Costa Counties, Calif., and in Kaui and Maui Counties in Hawaii.

In Pacific Coast States, plague has been reduced to a minimum among domestic rats by anti-rat sanitation and poisoning. By such reduction of rat and rat-flea populations there, the possibility of infected rats being introduced to east-bound commerce is decreased. Nine Western States now have cooperative State-Federal programs to prevent local plague outbreaks.

There is now in progress in the Southeastern States a murine typhus control program with the purpose of keeping down domestic rat and rat-flea populations for the ultimate object of reducing the number of cases of murine typhus. This program involves application of DDT dust for control of fleas, back-lot and alley sanitation, ratproofing, food-establishment sanitation, and finally poisoning for the control of rats. By such reductions of rat and flea populations, the likelihood is reduced of implantation of plague from westward areas even should infected rats be transported eastward.

By keeping the domestic rat and rat-flea populations at a minimum locally, transmission from native wild rodents to human beings by way of domestic rat-fleas can be held to a minimum.

Table 1

HUMAN PLAGUE OUTBREAKS IN THE UNITED STATES

City	Date	No. of Cases Reported	No. of Deaths
San Francisco, Calif.	1900-04	120	114
San Francisco, Calif.	1907-08	186	92
Seattle, Wash.	1907-08	3	3
New Orleans, La.	1914-15	31	10
Oakland, Calif.	1919	13*	13
New Orleans, La.	1919-21	25	11
Pensacola, Fla.	1920	10	4
Galveston, Tex.	1920	18	12
Beaumont, Texas.	1920	14	6
Los Angeles, Calif.	1924	41	34
Total		461	299

Human Diseases Harbored by Domestic Mice and Rats

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Rodents and their ectoparasites are hosts of a number of disease-producing viruses, rickettsiae, and bacteria which affect man, generally in proportion to the degree to which the rodent hosts associate with man. Some of these disease organisms are transmitted directly by the rodent through contamination of man's food, water, and quarters through infected urine and feces, and some by biting. Many are transmitted from rodent to man by their ectoparasites. In some cases, rodents simply appear to be the host of an ectoparasite which is the reservoir of the disease.

Domestic rats and mice* bring ectoparasites and disease-producing organisms closer to man more constantly than do the rodents of the fields and woods, and therefore are responsible for a large number of such illnesses.

Rattus norvegicus, Rattus rattus, and Mus musculus

FLEA-BORNE DISEASES

Plague and murine typhus are two of the best known diseases of domestic rodents transmissible to human beings, partly because of the high death rate caused by the first and because of the long illness induced by the second. House mice, although found infected, appear to be unimportant as hosts to these diseases.

Before adequate rat control measures were practiced in the United States and possessions, outbreaks of plague occurred in Seattle, Wash.; San Francisco, Oakland, and Los Angeles, Calif.; Galveston and Beaumont, Tex.; New Orleans, La.; Pensacola, Fla.; and Hawaii and Puerto Rico. The total number of reported cases in cities on the continent was 460 odd and the number of resulting deaths was 299. In Hawaii over 400 cases of plague were reported through 1949.

During 1945, the number of reported murine typhus cases totaled 5,179 on the mainland and 106 in Hawaii. Many cases probably were unrecognized.

The deaths and illnesses caused by these diseases have prompted extensive control measures which are responsible for the low incidence of these diseases today: fewer than a thousand cases of murine typhus and only one murine-based case of plague in Hawaii in 1949.

There are a number of other diseases, taking a less violent toll in sickness and death, that are not so well known, partly because rodents are not the sole reservoirs and partly because of the milder nature of the disease. In toto, however, they cause considerable illness.

High on the list of these is the group of alimentary-tract diseases of both domestic rats and mice. These include the feces-borne diarrheas, caused by various bacteria of the genus *Salmonella*; tapeworm infections; and the urine-borne leptospiral jaundice or Weil's disease.

SALMONELLOSIS

Salmonella enteritidis and *typhi-murium** are two bacteria which occur commonly in mice in all parts of the world. No animal, according to Cameron (2) has more favorable opportunity of infecting human food with its droppings than the house mouse (figure 1). Numerous outbreaks of acute gastroenteritis (food poisoning) in human beings have been attributed to the contamination of food by mouse droppings.

*This bacterium also is known as *Salmonella aertycke*

Figure 1. House mouse (*Mus musculus*), bearer of Salmonella (food infection) organisms and lymphocytic choriomeningitis. — Courtesy Earnest P. Walker

It is, unfortunately, difficult to determine what percentage of cases are caused by contamination of food by rats and mice, since contamination of food is caused also by flies and unwashed hands and by flesh of unhealthy animals.

Edwards and co-workers (3) record *S. typhi-murium* and *S. enteritidis* as common in domestic rats and mice. *S. enteritidis* is the more common. It is also common among turkeys, from which humans also may acquire it.

While culturing flea feces to determine the presence of plague infection, Eskey (7) discovered that a number of rat fleas were excreting *S. enteritidis* which they apparently had acquired from blood streams of mice infested with this organism. Although other species of fleas had previously been infected by feeding them on *enteritidis*-infected mice, the laboratory workers had not been able to infect healthy mice with the infected fleas. Eskey and his co-workers were able to transmit *Salmonella* organisms by the bite of infected oriental rat fleas and Northern rat fleas. In one instance, transmission was obtained by feeding fleas on a mouse which itself was infected by the bites of infected fleas, demonstrating that the infection can be transmitted from mouse to mouse by fleas.

Although house mice in nature seldom have fleas in any great number, the same mode of transmission may occur among rats which do have great numbers in the milder climates with high humidities.

Ilajna (8) found *Salmonella* in cultures from 47 specimens of human blood and concluded that there was reason to believe that certain of these organisms may cause septicemia (blood poisoning). He found *S. typhi-murium* present in two "rats" and in 31 "mice," probably domestic species, but does not state how many of each of these he

examined. He also found *S. enteritidis* and *S. anatum* present in one "rat" each.

Eskey concluded that the two common fleas found on rats in the United States may play an important part in the dissemination of *S. enteritidis* among rodents and that human infection might be contracted directly from the bite of the fleas or from infected flea feces contaminating food.

Prevention of infection, according to Hull (12), consists in the use of meat products and eggs from healthy animals and birds and in the protection of food supplies from contamination by rats, mice, and flies. It is possible that bites of fleas also should be avoided.

Innumerable single cases due to transmission by mice and rats probably occur in the United States, since most food-handling establishments that have not been ratproofed are infested by one or both of these domestic rodents during a part of the year. The great majority are infested all of the year.

LEPTOSPIRAL JAUNDICE

Human infections of leptospiral jaundice are caused by contamination of food and water by urine of infected animals. This disease, also called Weil's disease, is reported as seemingly becoming more common in North America (2). Mice and roof rats apparently are not as much infected as are Norway rats, which commonly bear the organism. Of 197 Norway rats examined from various districts in Honolulu, 9 were found infected, the spirochaetes being present in large numbers in the kidneys and excreted in the urine (1). Studies in various parts of the world have indicated that about 10 percent of domestic rats harbor the causative organism (12) but that adult rats living in sewers have been found 45 percent infected. In Chicago, to cite a summary by Hull, from 3 to 52 percent of the rats examined were found infected; in New York, N. Y., from 17 to 22 percent; in Nashville, Tenn., 10 percent; in Albany, N. Y., 40 percent; in Baltimore, Md., 7 percent; in Washington, D. C., 24 percent; in San Francisco, Calif., 33 percent; in Rochester, N. Y., 38 percent; and in Detroit, Mich., 16 percent. Although these percentages vary greatly due to location and time of year and with variable sizes of samples, they do show widespread and rather high rates of infection. Persons working in wet or damp premises are infected most commonly. Of the 73 cases tabulated by Hull, there were 8 sewer workers, 6 fish cutters, 10 swimmers, 3 abattoir workers, 2 eating-place operators, 1 butcher, 1 salesman in a meat and vegetable market, and 1 who lived in a rat-infested home.

AMEBIASIS AND TAPEWORM INFECTIONS

The several animal parasites that affect rats are not of great epidemiological importance (12). Food contaminated by rat droppings nevertheless may contain eggs of the rat tapeworms and dwarf tapeworms.

LYMPHOCYTIC CHORIOMENINGITIS

In five of six homes of patients ill due to lymphocytic choriomeningitis, investigated by Dr. Armstrong of the Public Health Service, according to Hull (12), house mice also were found infected, suggesting that possibly the patients had acquired the disease from the mice. In the sixth home, only two mice, both uninfected, were found, but the home previously had been overrun by mice.

Suspecting that house mice might be primary reservoirs, one worker, according to Hull, obtained 369 of these mice from 78 scattered homes in Washington, D. C., in order to determine to what degree they were infected. One mouse of every five examined was a carrier of the choriomeningitis virus. At least 45 percent of the homes in which the mice were taken had infected mice. In Boston, other workers found only 8 percent of 108 mice were carriers.

Other less extensive studies also have shown that the disease is most common among persons who have had direct and indirect contact with house mice prior to illness (12).

According to a memorandum from the CDC Epidemiologic Services, lymphocytic choriomeningitis is not a nationally notifiable disease, i. e., the Division of Public Health Methods and the National Office of Vital Statistics do not request the States to submit figures on the incidence of this disease. However, some States in some years have transmitted such figures to Washington, and they have been included in footnotes to either the quarterly or annual provisional summaries of incidence of notifiable diseases. In the final summary of incidence of notifiable diseases, published annually in a supplement to Public Health Reports, figures on lymphocytic choriomeningitis have been omitted. Table 1 shows the figures submitted by those States which gather data on the disease and which chose to transmit them to Washington.

Although the number of reported cases in the

Table 1

REPORTED INCIDENCE - LYMPHOCYTIC CHORIOMENINGITIS

States	1949*	1948**	1947**	1946**	1945**	Total
Ill.	-	-	-	-	2	2
Ind.	2	1	-	-	-	3
Iowa	1	-	-	-	-	1
Maine	-	1	-	-	-	1
Md.	-	-	-	-	6	6
Mass.	2	19	6	4	4	35
Minn.	5	1	5	-	2	13
Mont.	1	-	-	-	-	1
R. I.	-	5	-	-	-	5
Tenn.+	18	11	13	21	31	94
Utah	-	-	-	-	1	1
TOTAL	29	38	24	25	46	162

* Source of data: Quarterly summaries of notifiable diseases, Public Health Reports.

** Source of data: Preliminary annual summaries of notifiable diseases, Public Health Reports.

+ Includes choriomeningitis undefined.

United States is small, the desirability of keeping premises mouse-free is indicated.

Although infection via the respiratory tract is suggested by early symptoms, other possible routes of infection may be contaminated food or contamination through the skin or membranes. Present recommended means of prevention are construction of homes with a view to making them mouseproof and reduction or elimination of mouse infestation in quarters frequented by man.

HISTOPLASMOSIS

A fungus organism called *Histoplasma capsulatum* also has been found in Norway rats in Loundoun County, Va., (4,5,6) and in southwest Georgia (6). Although this disease affects human beings, the significance of the rat in the epidemiology of human cases is not yet apparent, according to Emmons. The disease is so poorly known in human beings that it is difficult to estimate the number of cases occurring annually. It is possible that rats and human beings both may acquire infection from some common source or that the rat, being closely associated with human beings, may heighten the chances of human infection by disseminating the infecting bodies of the *Histoplasma* organism. Dogs, however, also bear the disease organism.

RICKETTSIALPOX

During July 1946, a peculiar disease, later found to be a mouse disease transmitted by house-mouse mites (*Allodermanyssus sanguineus*) occurred in a middle-class housing development in New York City. An investigation of 80 cases during the succeeding 10 weeks showed that the disease resembled chickenpox and that it is mild (9,10,11). This disease is known only from New York City but the house-mouse mite is known to be distributed spottily over the United States, having been found in Salt Lake City, Utah; Tucson, Ariz.; Urbana, Ill.; Philadephia, Pa.; Indianapolis, Ind.; Boston, Mass.; and Washington, D. C. (15).

The mite is troublesome as a biter even though it may not be infected. It has been found on both domestic rats and mice, but it appears to be primarily a house-mouse parasite.

A related species *(Liponyssus bacoti)*, the tropical rat mite, is also a troublesome biter when it becomes common. It has been found capable of transmitting rickettsialpox from mouse to mouse in the laboratory (14), but appears to be a poor vector and is not known to transmit rickettsialpox other than under ideal laboratory conditions. It is much more common on domestic rats than on domestic mice. Apparently, this mite is not important in transmitting murine typhus from rat to rat or from rat to man. Ilowever, it causes most severe dermatitis when it bites.

RAT-BITE FEVER AND HAVERHILL FEVER

Occasionally the bites of rats are followed by a fever, due either to infection caused by a *Spirillum (minus)* or a *Bacillus (Streptobacillus moniliformis)*. Recently, a case of rat-bite fever in Montana was noted under circumstances indicating that house mice were responsible (13). A child, bitten by a house mouse, became ill with the disease in an area where she had no contact with rats. A high percentage of the house mice in the buildings in which she was bitten were infected with the spirilla.

The bites themselves are, of course, painful, particularly those of rats. In poor housing sections of cities, children and helpless adults frequently are bitten severly and sometimes killed.

SUMMARY

Domestic rats and mice are known to harbor a considerable number of disease-producing organisms or infected ectoparasites, bringing them into the homes of man. Few studies have been made to determine what percentages of such diseases as salmonellosis, lymphocytic choriomeningitis, toxoplasmosis, and others are transmitted by domestic rats and mice; but the fact that they do transmit them, along with the known vectorship of plague and murine typhus by rat fleas, adds up to the fact that these rodents are too dangerous to be allowed in the homes of man.

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Methods Used in Plague Transmission Studies

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In addition to its field work on plague, the Western Communicable Disease Center Laboratory carries on plague research activities. One of the more interesting types of research is concerned with transmission studies in which the vector efficiency of fleas is studied under varying conditions.

Ogata in 1897 (1) brought forth the theory that fleas were involved in the spread of plague among rats. Simond in 1898 (2) supported this theory experimentally, but assumed that flea feces were responsible for the transfer of the organism from

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