FLEAS OF PUBLIC HEALTH IMPORTANCE AND THEIR CONTROL

TRAINING GUIDE - INSECT CONTROL SERIES

Harry D. Pratt
Training Branch, Communicable Disease Center

and

John S. Wiseman
Texas State Department of Health

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Communicable Disease Center
Atlanta, Georgia

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INTRODUCTION

Fleas are of great importance as vectors of disease in many parts of the world. Public health workers are most concerned with fleas that carry the organisms of bubonic plague and murine typhus from rats to man and those that transmit plague among wild rodents and occasionally to man. However, many people are more concerned with fleas because of their insidious attacks on man and domestic animals, causing irritation, loss of blood, and extreme discomfort. In addition, fleas are known to serve as intermediate hosts for some species of dog and rodent tapeworms that occasionally infest man, and they may act as intermediate hosts of a filarial worm of dogs. Fleas may possibly be involved as vectors of *Salmonella* bacteria causing diarrhea and dysentery and of the bacteria causing tularemia. It is important for public health workers to become familiar with the few species that attack man, domestic animals, rats, and certain wild mammals.

Public health workers should know the more important habits and life histories of fleas in order to apply the most effective control methods. A knowledge of the habits and habitats of each species of flea is as important as familiarity with the effective insecticides in controlling these insects.

FLEAS AND HUMAN WELFARE

THE FLEA BITE

Flea bites are almost unbearable to some persons, while other people are not much disturbed by them. The development of sensitivity to flea bites requires an initial sensitization by the insect. Thus, a latent period occurs between the time of first exposure and the time when subsequent flea bites elicit skin reactions (Benjamini, Feingold, and Kartman, 1960). In people who have been bitten by fleas, reactions vary from small red spots (where the mouthparts of the flea have penetrated the skin) surrounded by a slight swelling and reddish discoloration to a very severe generalized rash. Relief from the irritation of a bite may be obtained by treatment with carbolated vaseline, menthol, camphor, calamine lotion, or other soothing medication.

SPECIES COMMONLY ATTACKING MAN

Although most fleas have a preferred host, many of them are known to take a blood meal from a wide variety of animals and will bite man readily in the absence of their normal host animal. The cat flea (*Ctenocephalides felis*) and the dog flea (*Ctenocephalides canis*), two of the most common species, may be very annoying to man. The adult fleas feed and mate on these pets. The female fleas lay their eggs among the hairs of these animals and the eggs drop off onto the mat or rug where the pets sleep or rest, onto carpets or overstuffed furniture, cellar floors, and similar places. Larval development usually requires at least two to three weeks and the newly emerged fleas simply hop onto cats or dogs as they walk about. However, if people leave their homes and take their pets with them, or "board" their cats and dogs at an animal hospital for two to four weeks or longer, enormous numbers of adult fleas may come through to maturity in a vacant house or apartment. These fleas have had no opportunity for a blood meal. When such people return to their homes, they are greeted by hundreds or thousands of hungry fleas and may suffer excruciating pain. In the summer, cat and dog fleas will breed out of doors in vacant lots, under houses, in barns, and similar situations, particularly if there are stray dogs or cats about. The human flea (Pulex irritans) occasionally becomes abundant on farms, particularly in abandoned pig pens. Many people are bitten by tiny, dark, wingless insects popularly known as "sand fleas." In the North "sand fleas" usually are cat or dog fleas associated with stray cats or dogs in vacant lots. In the West "sand fleas" may be human fleas associated with ground squirrels or prairie dogs. In the South "sand fleas" sometimes are sticktight fleas, but more commonly are cat or dog fleas. Along the beaches, tiny crustaceans belonging to the Order Amphipoda occurring abundantly in sea weed are often called "sand fleas", "sand hoppers", and "beach fleas."

The oriental rat flea (Xenopsylla cheopis) and the northern rat flea (Nosopsyllus fasciatus) normally spend most of their adult life on Norway and roof rats. However, when these rodents are killed, these fleas leave their rodent hosts and bite man readily. The western hen flea (Ceratophyllus niger) and the European hen flea (Ceratophyllus gallinae) occasionally become extremely abundant in chicken houses, occupied or vacant, and attack man in large numbers. On occasion other fleas, such as the squirrel flea (Orchopeas howardii) leaving the nests of their rodent host in attics or hollow trees, may bite man and cause great discomfort. Most people are familiar with the irritations and allergic reactions due to flea bites and welcome the assistance of public health workers in controlling these insects. Identification of the species of flea involved, its habits and preferred hosts will assist people in locating the source of the infestation and preventing these attacks.

DISEASES TRANSMITTED BY FLEAS

In the United States, fleas are most important in the transmission of murine typhus in the southern states and of plague in the western part of this country. These two diseases of rats and wild rodents are readily transmitted to man by the oriental rat flea and certain other fleas when conditions are favorable. Fleas are also involved to some extent in the transmission of the dog tapeworm (Dipylidium caninum) and of the rodent tapeworms (Hymenolepis diminuta and H. nana) which occasionally infest man and filarial worm of dogs. Eskey and co-workers (1949) have recently shown that the oriental rat flea and the northern rat flea may play a part in the transmission of Salmonella infections.

Plague. In his fine "History of Plague in the United States", Link (1955) has written "Historically, bubonic plague has been responsible for a number of notable pandemics. The disease appears to have a strong, long-term cyclic tendency. It flares up on a global scale and then slowly retreats to smoulder in endemic centers. During the last 15 centuries, four important pandemics have been recorded: the pandemic of 542 to 600 A.D., which began during the reign of the Emperior Justinian and involved the whole Roman world; the 'Black Death' of the 14th century, some of which was certainly plague, and which caused an estimated loss of 25 million lives, one-fourth of the entire population of Europe alone; the pandemic of the 15th, 16th, and 17th centuries, which culminated in the 'Great Plague of London', 1664 to 1665; and the present pandemic...." The present pandemic of plague probably began in the Chinese province of Yunnan in the middle of the 19th century, reached Canton and Hong Kong in 1894, and Calcutta and Bombay in 1896. From these major ports this disease spread to every continent. Many instances were reported of human beings on board ships who were sick with plague, including vessels docking at New York, N. Y.; Port Townsend, Washington; and San Francisco, California.

Plague in the United States. There are two epidemiological types of plague. One, urban plague, is the classical form of the disease and the type usually contracted in cities where people have close contact with domestic rats and their fleas. The second type, known as sylvatic plague, is more often contracted by persons in rural areas who have contact with wild rodents or their fleas. The latter form of plague is sometimes referred to as campestral plague. Both epidemiological types of the disease are caused by a bacterium, Pasturella pestis.

There have been 535 human cases of plague in the United States from 1900 through 1961 with 345 deaths. Table 7.1, slightly modified from Link (1955) shows that these cases and deaths have occurred in 13 states.

TABLE 7.1

HUMAN PLAGUE IN THE UNITED STATES 1900 THROUGH 1961*

State	Cases	Deaths
Arizona	1	0
California	415	285
Colorado	1	1
Florida	10	7
Idaho	1	1
Louisiana	51	18
Maryland	1	0
Michigan	1	0
Nevada	1	0
New Mexico	12	6
Oregon	1	1
Texas	31	18
Utah	1	0
Washington	8	8
Total	535	345

*101 cases with 62 deaths were of sylvatic origin, and 3 cases were laboratory contracted, one each in California, Maryland, and Michigan.

Urban Plague: It is quite likely that plague has been introduced repeatedly, by shipping, into major seaports on the Pacific and Gulf coasts. Plague was first recognized in North America in 1900 when the dread disease appeared in San Francisco. Some authorities believe that plague entered the city in infected rats escaping from a ship originating in the Orient. These rats died and the infected fleas transmitted plague to other rats and to people and wild rodents in the area. The first epidemic of plague in San Francisco is usually considered to have begun in 1900, with the discovery of a dead Chinese in a hotel, and to have ended in 1904. During this four-year period, there were 121 cases with 118 deaths. A second epidemic, in San Francisco, began in May 1907 and continued through October 1908 with 167 cases and 89 deaths.

In Seattle, plague first occurred in the fall of 1907. Link (1955) has written "although most official records show only three proved fatal cases, presumptive evidence indicates that there were seven deaths in 1907 and one in 1913."

Plague-infected rats were found in New Orleans in 1912 and 1914. During 1914 there were 30 cases of plague in humans, of which 10 were fatal. The disease continued in that city until 1920, with a total of 51 cases and 18 deaths for the years 1914-1920. Plague occurred in Pensacola, Florida, and in Beaumont and Port Arthur, Texas during 1920. In 1924-1925 there was an outbreak in Los Angeles with a total of 40 cases, 33 of the pneumonic type, with 35 deaths from both the pneumonic and bubonic cases.

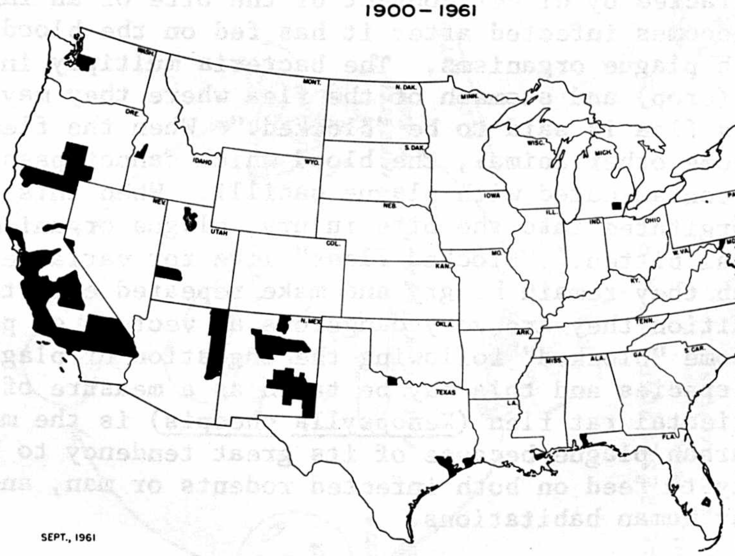
Sylvatic Plague: Human cases of plague resulting from contact with wild rodents and their fleas have occurred in California since 1908. Most of these have been single, widely separated, cases of sporadic occurence. However, in Oakland, California, a squirrel hunter became ill with plague in August, 1919, and died of the disease. His landlord, his nurse, and two visitors soon developed symptoms of a virulent type of "pneumonia." Seven similar instances of "influenza with pneumonia" materialized from these contacts resulting in 14 cases with 13 deaths in this small, self-limited epidemic which ended before rodent and ectoparasite control measures could be inaugurated. Since 1925 all known human cases of plague in the United States have been associated with wild rodents and wild rodent fleas. During this period there has been an average of about one human case of plague each year, with a lapse from 1951 through 1955 when none were reported. Plague infected animals or positive pools of fleas from wild mammals have been found over much of the United States west of the 100th meridian; as far eastward as western North Dakota (1941), Oklahoma (1944), western Kansas (1945), and western Texas (1946). Human cases of sylvatic plague have been reported from California, Oregon, Idaho, Utah, Nevada, Arizona, New Mexico, Colorado, and Texas.

In recent years, human cases of plague with some history or indication of association with wild rodents, have occurred in New Mexico (1949 to 1951 and 1959 to 1961), Arizona (1950), Colorado (1957), and California

(1956, 1959). Some of the epidemiological concepts of the disease may be illustrated by mention of a few of the established facts concerning recent human cases of sylvatic plague. In June 1956, in Ventura County, California, a man was bitten on the ankle, presumably by an infected wild rodent flea, and died seven days later despite medical treatment. In 1957, a child spent several weeks summer vacation with her grandparents at a rustic lodge located in a mountain valley in Boulder County, Colorado. An almost daily pastime for the youngster was the feeding of crumbs to chipmunks at a site not far from the home. She left Colorado in August for her parents' home in Wichita Falls, Texas, where she became ill with a diagnosis of "meningitis" and died on September 11, 1957. Plague organisms were found in autopsy material. Two human cases of plague occurred in California in 1959 and both recovered following treatment with newer antibiotics. One of these cases involved an eleven-year old boy who had slept on the ground in Yosemite National Park during a Boy Scout camping trip and the other a veterinarian in Sonora, California, who may have become infected while disposing of some dead rodents around his stable. The third reported case in 1959 involved a three-year old girl in New Mexico who died of bubonic plague in July and who may have been exposed to wild rabbits earlier in the month.

The New Mexico Department of Public Health reported two cases of plague in Air Force personnel who had hunted rabbits together in an area near Roswell, New Mexico, and 30 miles north of this community on February 19 and 20, 1960. The first case developed symptoms on February 23. The illness was quite severe. The second case developed on February 25, and was much milder. In 1961 two deaths have been reported: a sawmill worker at Pecos, New Mexico, and a Harvard geology professor who had been doing field work in the Santa Fe, New Mexico area and died in Massachusetts. A third case who recovered following treatment was reported during August 1961 in a power company lineman working in the Cowles, New Mexico area.

COUNTIES WHERE HUMAN PLAGUE HAS OCCURRED
1900 – 1961



SEPT., 1961

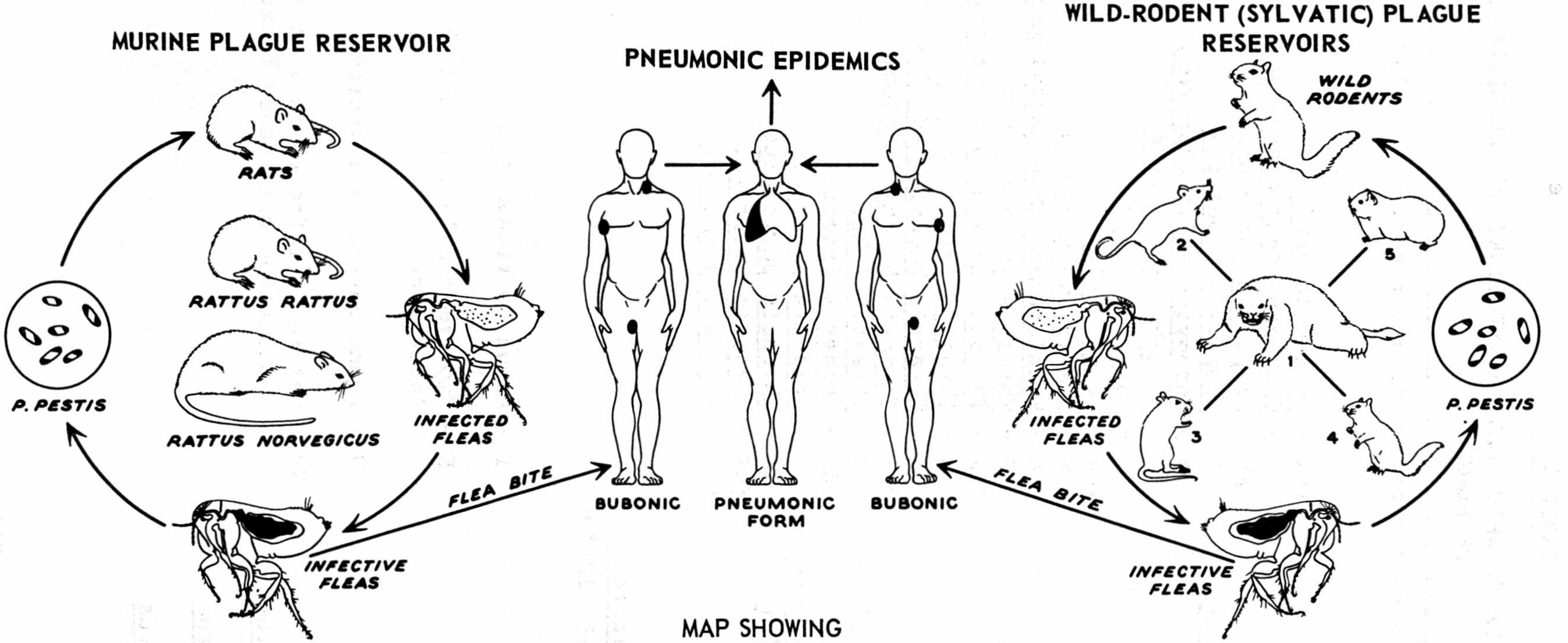
Fig. 7.1

At least 18 genera of North American mammals have been found to be infected with plague organisms. This has been learned from laboratory tests of the fleas or tissues from the animals. These animals include rats, ground squirrels, field mice, pack rats, chipmunks, rabbits, and other abundant species. In these wild animals the disease is referred to as sylvatic plague. It is only rarely transmitted from wild rodents to man, as most wild rodent fleas do not normally attack man. Lists of these mammalian hosts of plague are included in Link (1955) for the United States, and in Machiavello (1954) and Pollitzer (1954, 1960) for the world. Pollitzer has written that at least four groups of rodents constitute the great primary reservoir of sylvatic plague in the United States: ground squirrels on the Pacific Coast and the northern part of the inter-mountain plateau, wood rats in the southern deserts, prairie dogs in the plateaus of Arizona and New Mexico, and sage-brush voles and certain meadow mice in Oregon and Washington. Kartman, et al. (1958) would add a fifth group: the small rodents such as meadow mice and deer mice in California, and have written, "Historically, emphasis has shifted from the large colonial rodents such as ground squirrels, to the small inconspicuous native field voles and mice, as Microtus and Peromyscus. The coexistence of these small rodents with domestic rats in the vicinity of human habitations, and the prevalence of enzootic plague in these wild rodent populations, poses a potential threat which has as yet not been fully elucidated." Rabbits and hares are a sixth group which may be important, particularly in New Mexico (Kartman, 1960).

Mode of Transmission. Three clinical types of plague are recognized: bubonic plague, in which swellings (buboes) filled with plague bacteria develop in lymph nodes, especially those of the armpits or groin; pneumonic plague, which results in a highly contagious pneumonia-like disease; and septicemic plague, a massive blood poisoning or septicemia. When untreated, bubonic plague has a fatality rate of 25 to 50 percent or more; the pneumonic and septicemic types are usually fatal. Bubonic plague is normally transmitted to man by the bite of an infected flea, although the disease may be contracted by direct contact or the bite of an infected rodent. The flea becomes infected after it has fed on the blood of an animal infected with plague organisms. The bacteria multiply in the proventriculus (crop) and stomach of the flea where they may form an obstruction. Such a flea is said to be "blocked." When the flea attempts to feed on man or some other animal, the blood which cannot pass beyond the block, becomes contaminated with plague bacilli. When this contaminated blood is regurgitated into the bite injury, plague organisms gain entry into the animal bitten. "Blocked fleas" live for variable lengths of time during which they remain hungry and make repeated efforts to feed. In this condition they are very dangerous as vectors of plague. The tendency to become "blocked" following the ingestion of plague bacilli varies within flea species and this may be taken as a measure of vector efficiency. The oriental rat flea (Xenopsylla cheopis) is the most important vector of urban plague because of its great tendency to become blocked, its ability to feed on both infected rodents or man, and its great abundance near human habitations.

Figure 7.2

EPIDEMIOLOGY OF PLAGUE



PRINCIPAL RESERVOIRS OF MURINE PLAGUE:

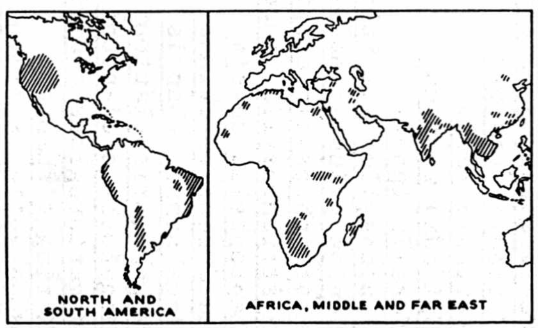
(1) Rattus rattus
(2) Rattus norvegicus

FORMS OF HUMAN PLAGUE

A. Infection through flea-bites leads usually to bubonic plague, less frequently to "septicaemic" plague without apparent buboes.

B. Direct spread of the infection through bubonic patients with secondary lung involvement is apt to lead to manifestations of primary pneumonic plague.

MAP SHOWING
INCIDENCE OF PLAGUE IN 1961



PRINCIPAL RESERVOIRS OF SYLVATIC PLAGUE:

(1) Marmota (Central Asia)
(2) Meriones (Western Asia)
(3) Tatera (South Africa)
(4) Citellus (South-East Russia, West of North America)
(5) Caviinae (South America)

Human plague of sylvatic origin is quite frequently contracted through direct contact with infected rodents and not through flea-bites.

In the United States the important reservoirs of sylvatic plague include ground squirrels, prairie dogs, wood rats, sage brush voles, meadow mice, deer mice, rabbits and hares

TABLE 7.2

A LIST OF FLEAS IN THE UNITED STATES WHICH MAY BE IMPORTANT IN THE EPIDEMIOLOGY OF PLAGUE

Modified and rearranged in alphabetical order after Pollitzer (1960) and Stark (1959).

N - Anomiopsyllus species
N - Anomiopsyllus hiemalis
EN - Anomiopsyllus nudatus
TEN - Atyphloceras multidentatus
N - Atyphloceras species
ENP - Catallagia decipiens
E - Catallagia wymani
T - Ctenocephalides canis
TEN - Ctenocephalides felis
TEN - Diamanus montanus
TEN - Echidnophaga gallinacea
N - Epitedia stanfordi
TEN - Epitedia testor
TEN - Epitedia wenmanni
N - Foxella ignota
EN - Hoplopsyllus glacialis affinis
TEN - Hoplopsyllus anomalus
TN - Hystrichopsylla dippiei truncata
TEN - Hystrichopsylla linsdalei
E - Leptopsylla segnis
TEN - Malaraeus telchinus
TEN - Megabothris abantis
NP - Megabothris clantoni
N - Megabothris clantoni clantoni
E - Megarthroglossus divisus divisus
NP - Meringis shannoni
E - Monopsyllus ciliatus
TEN - Monopsyllus eumolpi
TEN - Monopsyllus exilis
TENP - Monopsyllus wagneri
EN - Neopsylla inopina
TEN - Nosopsyllus fasciatus
T - Opisocrostis bruneri
TEN - Opisocrostis hirsutus
TEN - Opisocrostis labis
N - Opisocrostis tuberculatus cynomuris
TEN - Opisocrostis tuberculatus tuberculatus
TN - Opisodasys keeni nesiotus
N - Orchopeas leucopus
N - Orchopeas neotomae
TEN - Orchopeas sexdentatus
T - Orchopeas sexdentatus sexdentatus
EN - Oropsylla idahoensis
T - Oropsylla rupestris
N - Peromyscopsylla hesperomys adelpha
N - Pleochaetis sibynus
T - Polygenis gwyni
TEN - Pulex irritans
N - Stenistomera alpina
N - Stenistomera (Miochaeta) macrodactyla
TEN - Thrassis acamantis ssp.
TEN - Thrassis arizonensis littoris
TN - Thrassis bacchi bacchi
N - Thrassis bacchi gladiolis
NPT - Thrassis bacchi johnsoni
N - Thrassis fotus
TEN - Thrassis francisi
ET - Thrassis pandorae
EN - Thrassis petiolatus
TEN - Thrassis stanfordi
TEN - Xenopsylla cheopis

T - Known to transmit in laboratory

E - Experimentally infected in laboratory

N - Found naturally infected

NP - Naturally infected in a pooled inoculation with other fleas

Pneumonic plague is believed to have been involved in epidemics of the "Black Death" which, during the last 15 centuries, have killed millions of people in Europe and Asia. This clinical type of plague occurs secondarily to the bubonic type when plague organisms localize in the lungs. The plague bacteria are spread directly from person to person in sputum or droplets coughed up by the sick. In Manchuria in the winter of 1910-1911 more than 60,000 deaths were attributed to the pneumonic type of plague.

Murine Typhus. Murine typhus occurs in Europe, Asia, Africa, Australia, South and North America. Murine typhus is primarily a disease of domestic rats and mice and is caused by *Rickettsia typhi* (*R. mooseri* or *R. prowazeki* var. *typhi* of some authors). This organism is closely related to that which causes the much more serious epidemic typhus, a louse-borne disease that has caused the deaths of millions of persons. Fortunately, the fatality rate for murine typhus is low, about 2 percent, and the disease is much more severe in elderly individuals than in children. The incubation period of murine typhus in man is 6-14 days, most often 12 days, and the clinical course of the disease tends to be milder than in epidemic typhus. In the United States murine typhus is often confused with Rocky Mountain spotted fever since both diseases are characterized by rash and fever. Rocky Mountain spotted fever tends to be a disease occurring in spring and early summer, while murine typhus is more common in late summer and fall. According to Mohr (1951), the peak in the number of human cases of murine typhus corresponds rather well with the period of maximum abundance of the most important vector, the oriental rat flea. Murine typhus is spread from rodent to rodent by their fleas, lice and possibly mites, and occasionally to man from rats and mice, presumably by fleas. The most likely mode of infection is by organisms penetrating abraded skin at the site of flea bites contaminated by flea feces. Infection by direct bite remains a possibility, and infection by inhalation and ingestion is probable (Jellison, 1959).

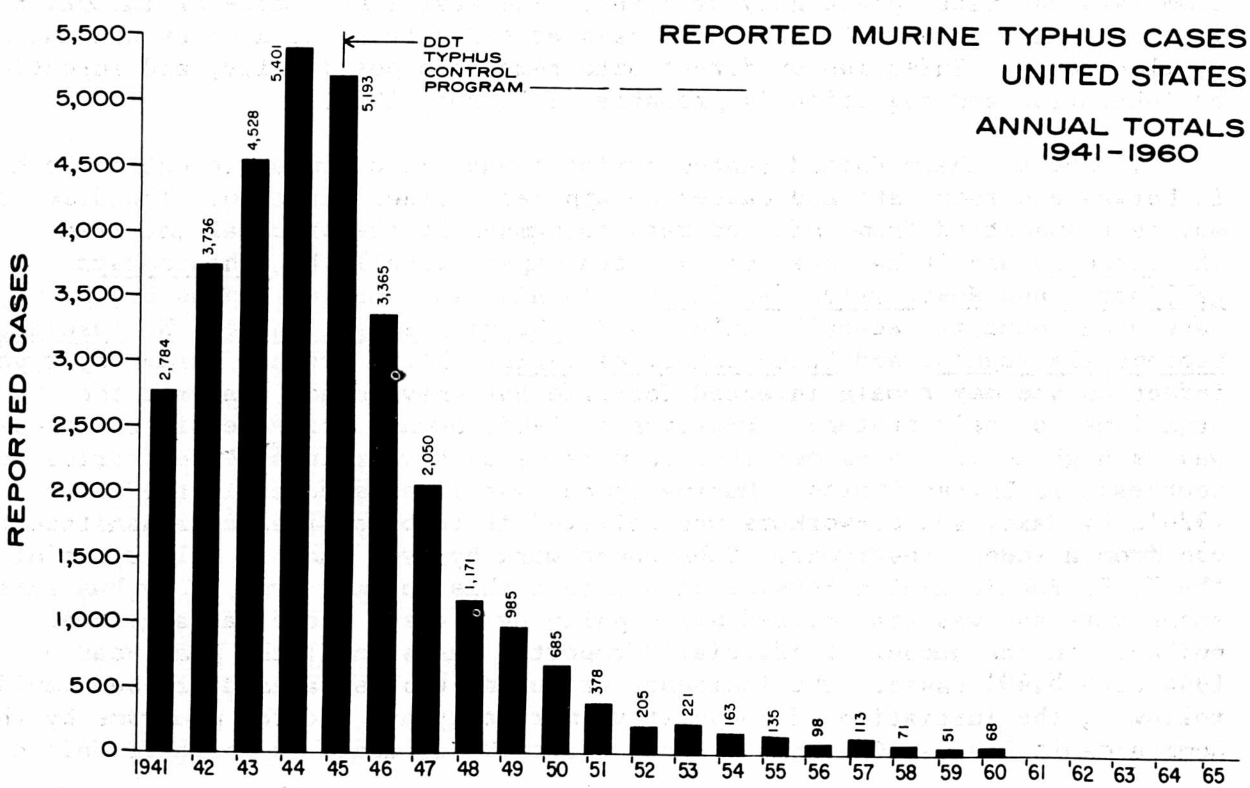
In the southern United States murine typhus is a common infection both in Norway and roof rats and causes no apparent illness in them. The disease may be transmitted from infected rats to humans by the oriental rat flea (*X. cheopis*) and it has been transmitted experimentally by *Echidnophaga gallinacea* and *Nosopsyllus fasciatus*. In addition, murine typhus organisms have been found in naturally infected *X. cheopis*, *E. gallinacea*, *N. fasciatus*, *Leptopsylla segnis*, and *Ctenocephalides felis*. Fleas are not harmed by typhus infection and may remain infected for life but they do not transmit the organisms to their progeny. Previous to 1945, human incidence of the disease was as high as 500 cases per 100,000 persons each year in a few countries in southeastern United States. Murine typhus was first studied in the early 1920's by Maxcy and co-workers who believed it to be a disease transmitted to man from a rodent reservoir. Subsequent work by Dyer and his colleagues of the U. S. Public Health Service showed that this endemic type of typhus existed among rats and was transmitted principally by fleas. There was a gradual build-up in the number of officially reported cases until the peak year of 1944 with 5,401 cases. The incidence of murine typhus cases decreased rapidly following the initiation of cooperative murine typhus control programs by the Communicable Disease Center and State Health Departments in southern United

States. In 1959 and 1960 there were officially reported to the U. S. Public Health Service 51 and 68 cases of murine typhus respectively, Figure 7.3.

Pratt (1958) has written that murine typhus has practically disappeared from many large cities and has experienced a dramatic drop in incidence throughout the United States coincidental with vigorous control measures. While the great majority of reduction in the number of murine typhus cases is probably due to rat killing and DDT-dusting to kill infected fleas, McCroan and co-workers (1955) believe that some of the decreased morbidity may be due to use of new antibiotics such as aureomycin and terramycin. These authors have written, "The reporting of all rickettsial infections has been adversely affected by the availability of effective chemotherapeutic agents. The rickettsial infections are so well masked by antibiotics that many cases are avoided and diagnosis with complete laboratory confirmation is a rarity." Continued progress in controlling rats and rat ectoparasites should prevent further build-ups of the disease.

Murine typhus control is based on the control of domestic rats and mice and their fleas as discussed later in this chapter. A vaccine has been developed against murine typhus comprising three initial injections with annual booster shots. Clinical cases of the disease have been successfully treated with a number of the newer, broad spectrum antibiotics such as chloromycetin, aureomycin, and terramycin.

Figure 7.3



Tapeworm Infections. Fleas serve as intermediate hosts for several species of tapeworms that occasionally infest man. One of these is the double-pored tapeworm of dogs (*Dipylidium caninum*), the immature stages of which have been found in *Ctenocephalides canis*, *C. felis*, and *Pulex irritans*. The eggs of this tapeworm are passed with dog or cat feces and are ingested by the larval stages of a number of insects including dog and cat fleas. The tapeworm larvae penetrate the wall of the insect gut and pass into the body cavity where they develop into the infective cysticercoid stage of the tapeworm which is carried through the flea pupae into adult fleas. Cat, dog, and human infestations result from accidental ingestion of infected insect hosts. The dwarf tapeworm (*Hymenolepis nana*) and *H. diminuta*, although essentially rodent endoparasites, frequently infest children. *Xenopsylla cheopis*, *C. canis*, and *P. irritans* serve as intermediate hosts for the dwarf tapeworm and *X. cheopis*, for *H. diminuta*.

Salmonellosis. The bacteria, *Salmonella enteritidis*, often cause outbreaks of so-called food-poisoning diseases, or acute gastro-enteritis. In severe cases there is great prostration and the outcome may be fatal. Meat and other foods contaminated by unsanitary conditions, including infective feces of rats and mice, are generally considered to be the prime sources of human infections. Varela and Olarte (1946) found that *S. enteritidis* survived in fleas (*P. irritans* and *C. canis*) up to 96 hours but transmission by bites was not demonstrated. Eskey and co-workers (1949) demonstrated that *X. cheopis* and *N. fasciatus* could transmit the infection to mice but the exact mode of transmission was not elucidated. Regurgitation into the bite wound seemed probable and large numbers of organisms were found in flea feces. Thus, it is possible that human infection can be contracted directly from the bite of an infected flea or from foodstuffs contaminated with their feces.

Filarial Worm Infections in Dogs. Heartworm of dogs, caused by a filarial worm (*Dirofilaria immitis*), is a very serious disease which frequently kills these animals (Kartman, 1957). Adult heartworms, which are found in the right ventricle of the heart and in the pulmonary artery, vary from 5 to 12 inches long. Some dogs have 50 or more worms in their hearts, wound around one another like balls of thread. These interfere with blood circulation, cause difficulty in breathing, and may even cause dogs to collapse after vigorous exercise. Newton and Wright (1957) reported that there are at least two canine filarial worms in the United States: (1) the true heartworm of dogs, *Dirofilaria immitis*, whose adults live in the heart and whose immature forms develop in, and are transmitted by, mosquitoes; and (2) a species of *Dipetalonema*, probably *D. reconditum*, whose adults occur in subcutaneous areas throughout the body and whose immature forms develop in, and are transmitted by, cat and dog fleas. This last species is probably the one studied by Steuben (1954) who found that they would develop in the body cavity of the cat, dog, oriental rat, sticktight, and squirrel fleas. Newton and Wright (1957) listed good differential characteristics for distinguishing these two species and summarized the importance of their discovery as follows: "With the heavy metal preparations and surgery that are being used as therapy, one would probably wish to be certain that the infection under treatment is heartworm and not some small, perhaps innocuous, subcutaneous filariid."

Other Diseases. Fleas have been mentioned as vectors of the following diseases:

Tularemia. Fleas can become infected with tularemia organisms and remain carriers of the bacteria (*Pasteurella tularense*) for a month or more, but they are probably not important vectors. In the United States the following species of fleas have been found naturally infected with the bacteria: *Diamanus montanus*, *Cediopsylla inaequalis*, *C. simplex*, *Nosopsyllus fasciatus*, and *Thrassis bachi*.

Leishmaniasis. Fleas have been reported as vectors of infantile and canine leishmaniasis in the Mediterranean region but Chandler and Read (1961) did not believe that they were involved in the transmission of these diseases.

Trypanosomiasis. Fleas transmit the non-pathogenic trypanosome (*Trypanosoma lewisi*) of the rat. However, the causative agent of Chagas' disease (*T. cruzi*) undergoes rapid degeneration in the flea (Chandler and Read, 1961).

Relapsing Fever. Chandler and Read (1961) asserted that the spirochetes of relapsing fever do not develop in the flea.

Miscellaneous. To the list of disease entities in which fleas may play some role, Jellison (1959) added myxomatosis, a disease of wild and domestic rodents; anemia due to exsanguination; dermatitis or flea allergy; and *Tunga* infestation, a special pathological condition.

BIOLOGY OF FLEAS

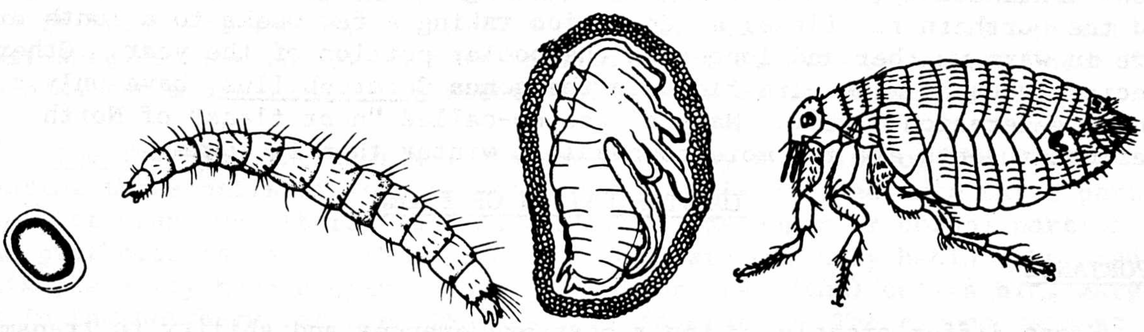
CHARACTERISTICS AND HABITS

Fleas are small, wingless insects varying from 1 to 8.5 millimeters in length, averaging 2 to 4 millimeters. The name of the flea order Siphonaptera, refers to their method of feeding through a siphon or tube, and their wingless condition. The flea is a narrow insect compressed laterally with backwardly directed spines, adapting it for moving about between the hairs and feathers of mammals and birds. Most species move about a great deal, and remain upon the host only part of the time in order to obtain a blood meal. The mouthparts consist chiefly of 3 stylets that are used to penetrate the skin of the host and form a tube for sucking blood. Both sexes feed upon blood and the female requires a blood meal before producing eggs. The powerful, long legs are adapted for jumping as much as 7-8 inches vertically and 14-16 inches horizontally.

Most species infest the smaller mammals such as rodents, rabbits, moles, and bats. Fewer species are parasitic upon the larger animals and birds. Most fleas are rather specific in their host preference, feeding on only one type of host, i.e., closely related species in the same genus, while others have developed an ability to feed upon various hosts. Fleas are very sensitive to extremes of temperature and humidity. This explains the relative abundance of fleas infesting animals that live in burrows and sheltered nests and the light infestations of fleas on mammals or birds that have no permanent abode or live in nests exposed to the elements. Nests furnish an abundance of organic food for flea larvae leading to a high rate of survival. Fleas infesting burrowing or nocturnal animals tend to have poorly developed eyes, or their eyes may be absent. Those infesting animals active during the day are more likely to have well-developed eyes. Some fleas feed at frequent intervals - once a day or more often. They are easily disturbed and seldom complete a meal at one feeding. *Pulex irritans* continues feeding after the digestive tract is gorged, causing the passage of undigested blood in the feces.

LIFE CYCLE

The four stages of development of fleas are egg, larva, pupa, and adult, a type of life history known as complete metamorphosis. The time for completion of the life cycle from adult to adult varies according to species, temperature, humidity, and food. Under favorable conditions in some species, a generation can be completed in as little as two to three weeks.



Egg Larva Pupa Adult

Figure 7.4. Life History of the Flea

Mating usually takes place on the host animal. The sticktight flea, *Echidnophaga gallinacea*, and the chigoe, *Tunga penetrans*, are unusual in that the female remains attached in one location for long periods of time and mating may take place while she is feeding.

Eggs are usually deposited among the hairs or feathers of the host or in the nest. They are smooth, spherical to oval, light colored, and large enough to be seen with the naked eye. Since they are not sticky or attached to the host, the eggs drop onto the ground or into the nest or bedding of the host - a factor important in explaining the later high concentration of adult fleas in dog or cat boxes or kennels, and on certain rugs or portions of a building. A flea's full quota of eggs is not laid all at once, but singly or in small batches, over a considerable period of time punctuated by blood meals which are necessary for their development. Successive matings are not necessary for the fertilization of future eggs, as the sperms from the initial pairing are stored in the spermatheca of the female and used as required. The eggs hatch in two days to several weeks depending upon temperature and humidity.

Larvae are small, 13-segmented, worm-like creatures without legs but with chewing mouthparts. The blind, active, whitish flea larvae are often found in the house in floor cracks and rugs, or in kennels, stables, chicken coops, animal burrows, and nests. The larvae feed on all types of organic debris, such as food crumbs, animal hair, or dry flea feces which is composed of more or less digested blood. The three larval stages may be completed in a week to several months.

Pupae are usually enclosed in a cocoon of finely spun silk encrusted with granules of sand, or various types of debris. The pupal stage lasts from a week to as long as a year.

After emergence from the cocoon, adults are usually ready to feed after 24 hours. Mating usually follows the initial blood meal. Very little is known about the time involved in the life cycle of most species or how many broods may be produced in a year. Some species apparently breed continuously, (such as the cat and dog fleas, oriental rat fleas, and the northern rat fleas) a generation taking a few weeks to a month or more in warm weather and longer in the cooler portion of the year. Other species, such as many bird fleas in the genus Ceratophyllus, have only a single generation a year. Many of the so-called "nest fleas" of North American rodents are far more abundant in winter than in summer.

IDENTIFICATION OF FLEAS

IMPORTANCE

Fleas differ greatly in their host preferences and ability to transmit human diseases. Therefore, it is necessary to know which species are prevalent in order to appraise the possible disease significance and plan suitable control methods. Hopkins and Rothschild (1953) estimated that there were about 200 genera and 1,100 species of fleas in the entire world, while Jellison and his co-workers (1953) reported that there were 72 genera, 243 species, and 55 subspecies described in North America north of Mexico through the year 1950. Smit (1958) stated that more than 1600 different species of fleas were known and that probably another thousand await discovery and description. Of the known species, 95 percent occur on mammals and 5 percent on birds.

Fortunately, only a few of these fleas are important to man as pests or as carriers of human diseases. The important species in the United States can usually be determined by means of the simple pictorial key in this chapter, figure 7.6. These species are reasonably easy to identify as the important characters are few and easily seen. All persons concerned with flea control should be able to recognize the fleas that attack man, and the most common fleas attacking local rodents and domestic animals. Most of the important characters are shown and labeled in figure 7.5.

FLEA ANATOMY

Fleas have the body divided into three regions: head, thorax, and abdomen. Structures on all three of these regions are used in identification.

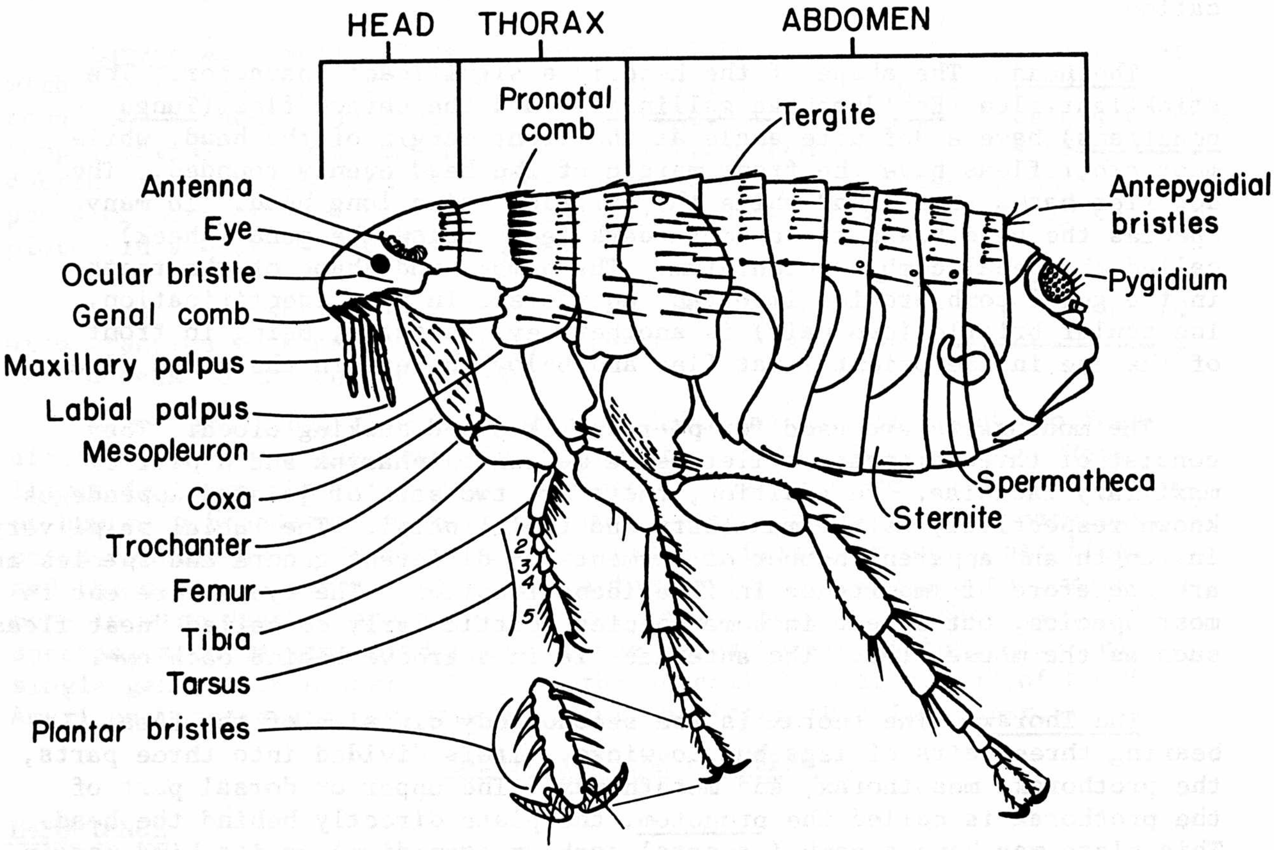
The Head. The shape of the head is a significant character. The sticktight flea (*Echidnophaga gallinacea*) and the chigoe flea (*Tunga penetrans*) have a definite angle at the front margin of the head, while most other fleas have the front margin of the head evenly rounded. The dog flea has a short head while the cat flea has a long head. In many species the head bears two or more dark teeth below the gena (cheek) called the genal comb or ctenidium. The number and shape of the teeth in the genal comb provide important characters in flea identification. The ocular bristle (eye hair) is another key character, being in front of the eye in the oriental rat flea and below the eye in the human flea.

The mouthparts are used for piercing skin and sucking blood. They consist of three elongate stilettos, a median epipharynx and a pair of maxillary laciniae. In addition, there are two sets of jointed appendages known respectively as the maxillary and labial palpi. The labial palpi vary in length and apparent number of segments in different genera and species and are therefore of importance in flea identification. The eye is present in most species, but absent in some species, particularly so-called "nest fleas" such as the mouse flea. The antennae lie in a groove behind each eye.

The Thorax. The thorax is the second body division of the flea, bearing three pairs of legs but no wings. It is divided into three parts, the prothorax, mesothorax, and metathorax. The upper or dorsal part of the prothorax is called the pronotum, the plate directly behind the head. This plate may have a comb (pronotal comb or ctenidium) on its hind margin as in the northern rat flea (*Nosopsyllus fasciatus*). The second segment of the thorax, the mesothorax, has a lateral plate or mesopleuron on each side directly above the base of the second leg. In most species of fleas, the mesopleuron is strengthened by an internal rod-like thickening. This is absent in a few species such as the human and sticktight fleas and is used as an important character in distinguishing these fleas from the oriental rat fleas. The posterior margin of the mesothorax and metathorax may bear spinelets which are often used in distinguishing families of fleas.

The Legs. The leg of the flea is composed of five main parts as follows: a large flat coxa, a small trochanter, a stout femur, a long tibia, and a five-segmented tarsus (or foot). All segments have spines or hairs of various sizes and lengths that are useful in identification. For example, Hopkins and Rothschild (1953 p. 361) illustrate arrangements of hairs on the hind tibiae that are apparently more reliable in separating cat and dog fleas than the shapes of the heads of these two species. The last segment of the tarsus bears plantar bristles that are important in distinguishing species of fleas, such as the northern rat flea and the squirrel flea.

Figure 7.5 Diagram of flea with parts labeled



<u>How to Use Pictorial Keys in Identifying Common Fleas</u>. Fleas can be identified by use of the pictorial key, page VII-17, using the structures illustrated in Figure 7.5 and described on pages VII-15 and VII-18. In identifying fleas with the "Pictorial Key to Some Common Fleas in the United States", first observe the head and thorax and determine in which of the three groups the specimen belongs: those with genal and pronotal combs present, those with only the pronotal comb present, or those with genal and pronotal comb absent. After this choice has been made, other characters are used in a similar manner to work downward on the key to the correct common and scientific names of the particular flea. These characters include number of teeth and position of the genal comb, shape of the head, length of the labial palps, position of the ocular bristle, number and position of the plantar bristles, and shape and coloration of the spermatheca in female specimens.

PICTORIAL KEY TO SOME COMMON FLEAS IN THE UNITED STATES

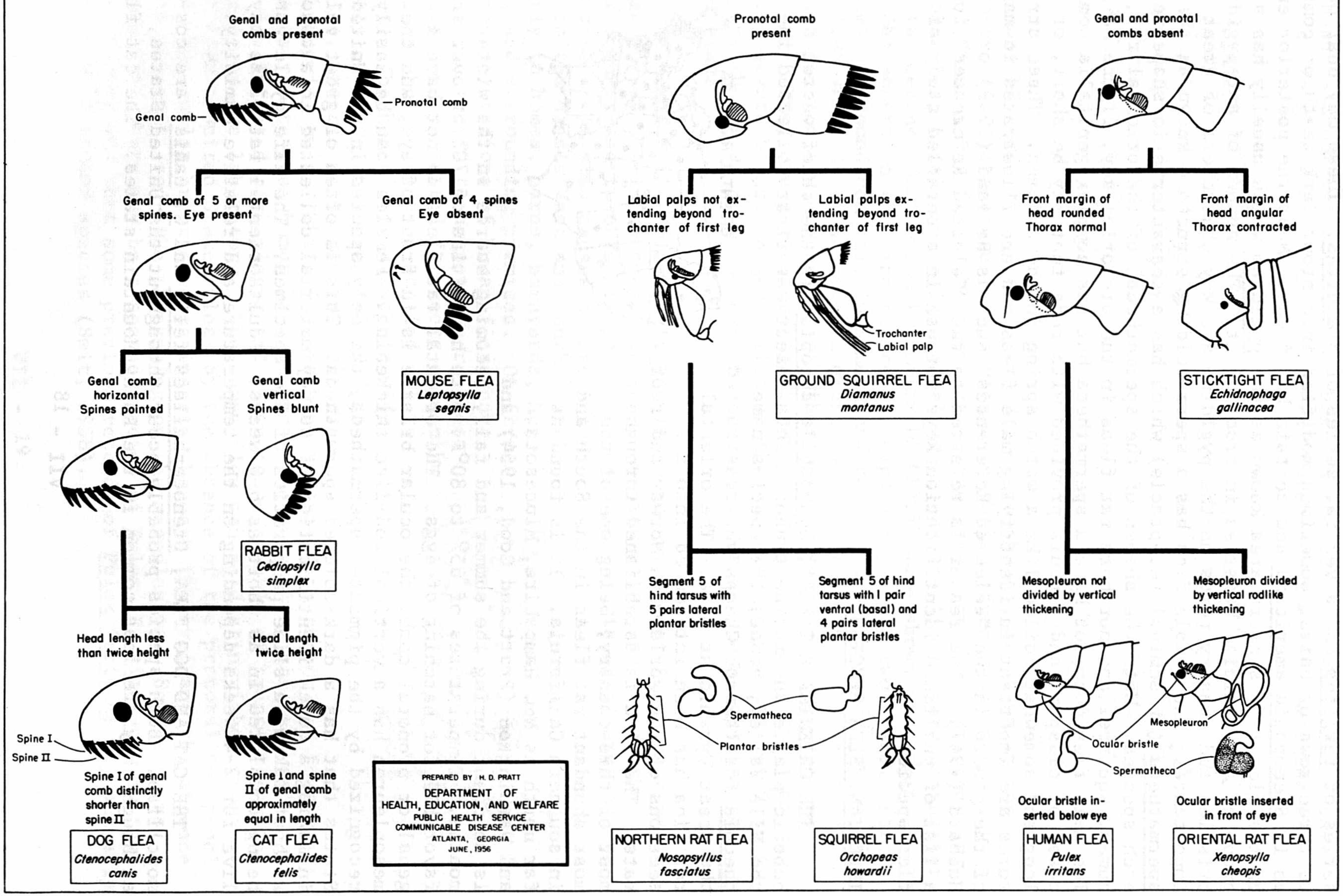
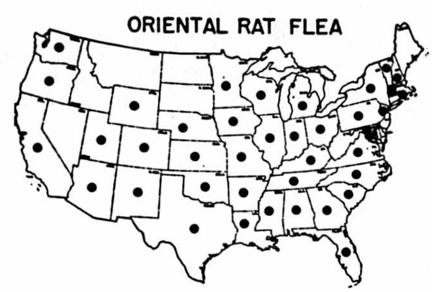


Figure 7.6

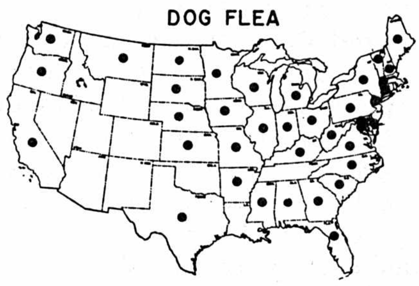
The Abdomen. The abdomen is covered by two sets of plates, a dorsal series of tergites and a ventral series of sternites. These may bear one to three rows of hairs, sometimes modified into stout dark teeth or combs as in *Stenoponia americana* and certain bat fleas. Near the posterior end of the flea is a sensory area known as the pygidium which usually has a group of antepygidial bristles in front of it. The number of antepygidial bristles and sensory pores on the pygidium are key characters of great importance. The female flea has a sperm-holding structure known as the spermatheca (or seminal receptacle) which has a characteristic shape in each species. Note the shapes of the spermathecae of the oriental rat, human, squirrel and northern rat fleas in the pictorial key, figure 7.6. The male flea does not have a spermatheca but has complex genitalia composed of claspers and a penis provided with rods that may be short, or long and somewhat coiled like a watch spring in the abdomen. These structures are important in identifying male fleas and are illustrated in many of the papers in the "Selected References" such as Holland (1949) or Hubbard (1947). The reader is referred to the "Selected References" for a list of published identification keys for use in a detailed study of flea species.

IMPORTANT FLEA SPECIES

THE ORIENTAL RAT FLEA, *Xenopsylla cheopis*, is the chief vector of bubonic plague and murine typhus. This insect was first collected in the Nile Valley; hence, the species name *cheopis* for Pharaoh Cheops who constructed the Great Pyramid at Giza. The oriental rat flea has been introduced into all sections of the world with Norway and roof rats. The flea is established throughout most of this country, being one of the most abundant rat fleas in the South and in southern California. It is found as far north as New Hampshire, Minnesota, and Washington (Pratt and Good, 1954) and is abundant during the summer and fall, becoming scarce in the winter months. Temperatures of 65^{o} to 80^{o}F. with humidities of 70% or over are favorable for hatching of eggs. The oriental rat fleas do not have a genal or pronotal comb, the ocular bristle is in front of eye, and the mesopleuron has a vertical rod-like thickening. Females can be easily recognized by the pigmented spermatheca, the only species in the United States that has a dark-colored spermatheca. This is often of great value in making a quick identification of survey material collected in alcohol without making a slide preparation of the specimen. The life cycle varies, being completed in as short as 6-8 weeks. Adult oriental rat fleas may live for 2-4 weeks depending on the temperature and relative humidity.

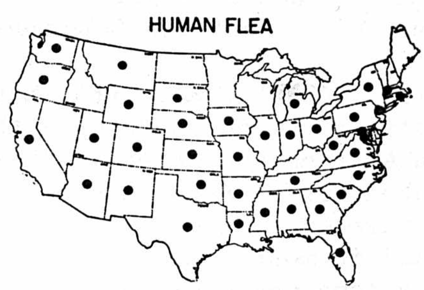


THE CAT AND DOG FLEA, *Ctenocephalides felis* and *C. canis*, are cosmopolitan. Both species probably occur throughout the United States, although they are less common in the Rocky Mountain states. The cat flea seems to be more abundant and generally distributed than the dog flea. The head is about twice as long as high in the cat flea while it is only about as long as high in the dog flea. Moreover, the front margins of

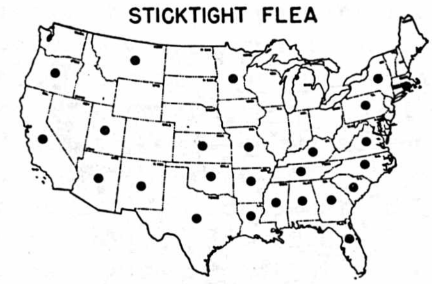


the heads of these two species have different shapes, as shown in the pictorial key. The angle is more acute in the cat flea than in the dog flea. In most cat fleas the first and second teeth on the genal comb are approximately equal, while in typical dog fleas the first tooth is shorter than the second. Hopkins and Rothschild (1953) have shown that there are good characters on the hind tibiae for separating these two fleas. Both species are found commonly in homes, under houses, or in yards, preferring locations where dust and organic debris accumulate. These fleas attack cats, dogs, and a wide variety of other mammals such as foxes, racoons, and rats. They are serious pests of man particularly during the summer, causing severe bites. A generation of the cat flea requires about 2 to 4 days for the eggs, 8 to 24 days for the larvae, and 5 to 7 days for the pupal stage.

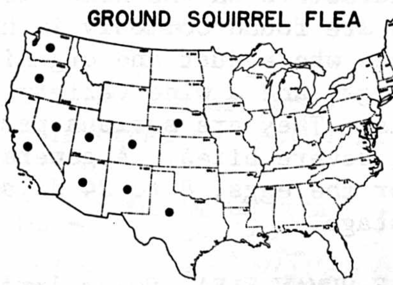
THE HUMAN FLEA, Pulex irritans, is found throughout the warmer parts of the world. It is the most important species attacking man on the Pacific Coast and is often responsible for a dermatitis or allergy due to flea bites. It also causes severe annoyance in the Middle West and South, particularly in homes, barns, barnyards, hogpens, and surrounding premises. On farms severe infestations of human fleas have often been traced to hogpens where these insects have persisted for weeks or months after the hogs have been carried off to market. The human flea attacks a wide variety of hosts including swine, dogs, coyotes, prairie dogs, ground squirrels, and burrowing owls. This flea has been collected on these last four hosts in areas remote from human habitations. The human flea has been experimentally infected with plague and shown to be capable of transmitting the bacteria in the laboratory. The human flea can be distinguished from other common United States fleas by the absence of the pronotal and genal combs, the ocular bristle being inserted beneath the eye, and the absence of the internal, rod-like thickening on the mesopleuron. Some workers believe that there may be a second species of Pulex, P. simulans, in the United States and that some previous records of Pulex irritans may actually refer to this second species (Smit, 1958).



THE STICKTIGHT FLEA, Echidnophaga gallinacea, is a small species that attaches firmly to its host during the adult stage, often forming ulcers on the head and neck of domestic fowl. The eggs are deposited in these ulcers and, after hatching, the larvae crawl out and drop to the ground to feed upon organic matter. All stages may be found in poultry yards and adjacent buildings. This flea attacks rats, cats, dogs, rabbits, ground squirrels, horses, fowl, and many other animals, including man. E. gallinacea has been found infected with plague and can be infected with murine typhus. This flea plays a minor role in disease transmission because the females remain fastened to one host for most of their lives.

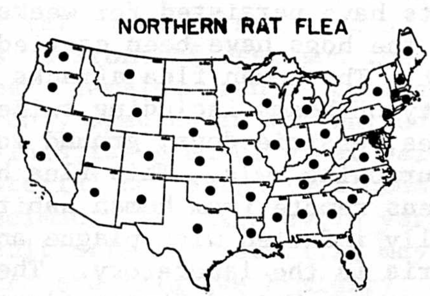


THE GROUND SQUIRREL FLEA, Diamanus montanus, is a dark brown, medium-sized flea with a very long labial palpi found on ground squirrels (Citellus) from Nebraska and Texas to the Pacific Coast. It is capable of transmitting plague among wild rodents. Laboratory tests have shown this flea to be about half as efficient as the Northern rat flea, Nosopsyllus fasciatus, in serving as a vector for plague. Species of Thrassis, Opisocrostis, Oropsylla, Monopsyllus, and Orchopeas have also been found to be capable of transmitting plague in laboratory tests.

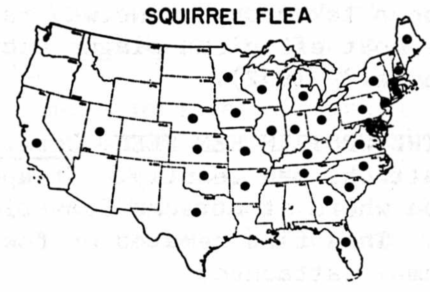


Hoplopsyllus anomalus is a major ectoparasite of ground squirrels (Citellus), and is a proven vector of plague (Stark, 1958). H. anomalus is found from southern Colorado westward into California.

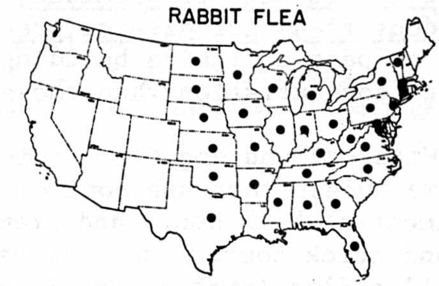
THE NORTHERN RAT FLEA, Nosopsyllus fasciatus, is commonly found on domestic rats and house mice throughout North America and Europe. This flea is not abundant in areas having an extremely warm climate. It does not readily bite man and is most commonly found in temperate regions where plague is not a severe problem. It is the predominant rat flea in the northern United States and is well established in Canada. This species may be of importance in transmission of plague organisms from rat to rat. It has been taken from wild rodents on a few occasions.



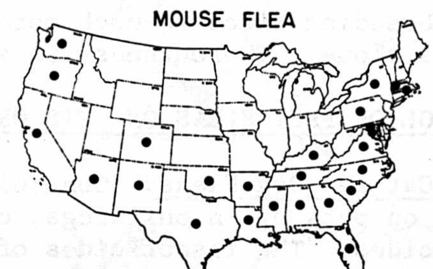
THE SQUIRREL FLEA, *Orchopeas howardii*, is found commonly in eastern United States, and also in the west, wherever gray squirrels occur. It is sometimes a serious household pest if these squirrels build their nests in attics and are later killed or excluded from the house by rodent stoppage. In such cases, the fleas which breed in the nest material, attack people in the attic or invade other parts of the building. Control is obtained by removal of the nest and application of insecticides.



THE RABBIT FLEA, *Cediopsylla simplex*, differs from the cat and dog flea in having the genal comb almost vertical rather than horizontal, and the teeth of the genal comb blunt or rounded rather than pointed, see figure 7.6. It is found commonly on rabbits in eastern United States and is known to bite outdoor loving humans such as hunters and hikers. In western United States there are other rabbit fleas similar to *Cediopsylla simplex* of the pictorial key.



THE MOUSE FLEA, *Leptopsylla segnis*, is easily recognized by the genal comb with four teeth. It was introduced into the United States many years ago with rats and mice. The mouse flea is most commonly found on domestic rats throughout the Gulf States and in parts of California, and less commonly on the house mouse, *Mus musculus*. This flea is most abundant along the east and west coasts near the original ports of entry. It is found in lesser numbers inland. This cool weather flea is relatively scarce in summer. It is considered to be a poor vector of murine typhus. It can be infected with plague in the laboratory, and has been found naturally infected with murine typhus in China.



THE CHIGOE, *Tunga penetrans*, is the pest which inspired the sailor's oath, "I'll be jiggered." It is a small, burrowing flea found in tropical and subtropical regions in North and South America, the West Indies, and Africa. It is not known to have become established in the United States. The flea is unusual in that the female actually burrows into or becomes embedded in the skin of the host. Engorgement with blood and the development of eggs cause great distension of the flea abdomen. Man is most frequently attacked between the toes or under the toenails where the flea may swell to the size of a small pea and cause excruciating pain. Inflammation and formation of ulcers may result. Secondary infection may cause tetanus or gangrene. *T. penetrans* is related to the sticktight flea.

THE COTTON RAT FLEA, Polygenis gwyni, is a parasite of the cotton rat, Sigmodon hispidus, in the southeastern and southwestern states. Specimens have been taken on the Norway rat, dog, and opossum. This species is one of the most efficient plague vectors among North American rodent fleas (Holdenreid, 1952).

THE WESTERN HEN FLEA, Ceratophyllus niger, is a dark, active species that attacks man readily. It appears to be confined to western North America where it attacks domestic and wild fowl. It breeds in fowl droppings. This flea remains on fowl only to feed for a brief period and does not remain attached.

FLEA CONTROL

Flea control may be divided into two main categories: control of pest fleas on pets or premises, primarily of cat and dog fleas, and control of rodent fleas for disease prevention. Insecticides for the control of fleas on pets or inside buildings are usually less toxic and are used at a lower concentration than those applied outside buildings (Table 7.3).

With cat and dog fleas reinfestation will occur within a short period of time unless thorough control procedures are carried out. Simultaneous treatment of both hosts and premises gives a much better chance of economical and quick control than either alone. Thus, if a cat or dog is treated to kill a flea infestation, it will soon become heavily infested again unless all nearby flea breeding sites are treated. It is necessary to know the habits of the animal in order that its favorite resting places will be known. A treatment of the infested animal plus a complete coverage of all flea breeding sites is much more effective than weekly treatments of the animal alone. Thoroughness is also required in controlling rodent fleas.

CONTROL OF PEST FLEAS ON PETS OR PREMISES

Cat and Dog Fleas. Control of cat and dog fleas, the usual species found on pets or in buildings, can be accomplished with a number of insecticides. The insecticides of vegetable origin, rotenone or pyrethrum, are safe to use on cats, kittens, puppies, dogs and other domestic animals. Dusts containing 0.75 to 1 percent pyrethrum or rotenone, or 0.2 percent pyrethrum plus synergists such as sulfoxide or piperonyl butoxide, may be used safely on cats, kittens, or puppies which might be affected by chlorinated hydrocarbons such as DDT. Cats, in particular, lick their fur so the chlorinated hydrocarbons have not been recommended for controlling their ectoparasites. These vegetable insecticides are safe to use and give effective control for 3 to 4 days. Some authorities feel that pyrethrum stuns, but does not kill, cat and dog fleas. Therefore, it has been recommended that the affected animal be dusted over a piece of newspaper, the paralyzed fleas brushed or combed out of the animal's fur, and the newspaper with the fleas burned to prevent reinfestation of the pet or premises. Pyrethrum and rotenone can be used safely to control ectoparasites on most domestic and laboratory animals. However, rotenone should not be used on pigs since they are particularly susceptible to it.

Since 1944 and 1945 the chlorinated hydrocarbon insecticides have been used for the control of cat and dog fleas on dogs. These include 5 percent DDT, 2-4 percent chlordane, or 1 percent lindane as dusts. Dusts are far safer to use than sprays because the insecticides are less likely to be absorbed through the skin in the dry form. Dusts also produce less odor and do not affect the skin as much as sprays. However, in many parts of the United States where DDT, chlordane, lindane and similar insecticides have been used for a number of years, cat and dog fleas are not being controlled on pets today as effectively as they were in the middle 1940's, possibly as a result of resistance developing to these chlorinated hydrocarbons.

For several years, malathion has been used for flea control on cats and dogs. It is used as a 1 to 5 percent dust or as a 0.5 percent spray. The senior author has used 3 percent malathion dust to control cat fleas on a female cat and three successive litters of kittens with no apparent harm to the animals. The fleas were controlled for 7 to 10 days following each treatment. Malathion is also suitable as an animal dip at 0.25 percent concentration, but the treatment should be done under the supervision of a veterinarian.

With all these insecticides the dust is applied to the fur with a shaker, or by hand, and rubbed in to give a complete treatment. Avoid getting the dust into the eyes, nostrils, and mouth of the animal. Also avoid making heavy applications to the abdomen as the material will be licked off by the pet. Start the application above the eyes on the head and cover all areas backward to the tail and haunches, being certain to treat thoroughly around the ears and underneath the forelegs. A tablespoonful of dust will treat a small animal, while as much as an ounce will be required for a large dog. Frequently following the application of insecticidal dusts, fleas become extremely active and make cats and dogs most uncomfortable for some time.

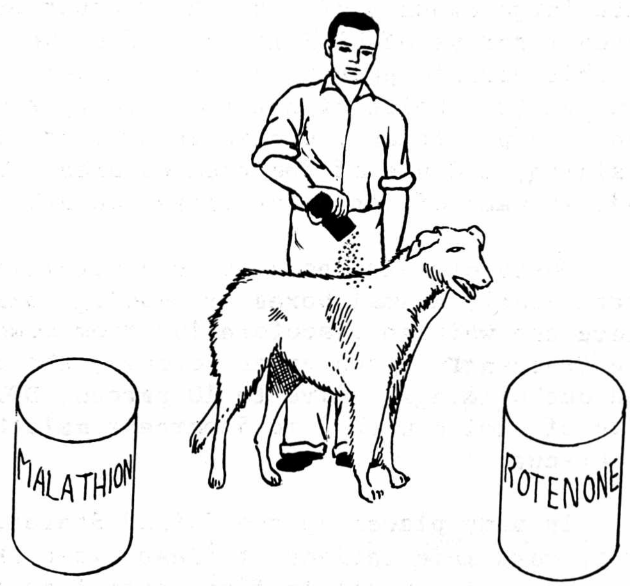


Figure 7.6 Dusting dog for flea control

A new development in the control of fleas and other ectoparasites on dogs is the use of one of the less toxic organic phosphorus insecticides, ronnel, as a systemic insecticide. **Pills containing ronnel are sold** only by or on the order of a licensed veterinarian. For a 10 pound dog, one 500 milligram tablet is administered every 2 days for 4 treatments, then 1 tablet weekly thereafter to prevent reinfestation. Dogs weighing 20 or more pounds may require 2 or more times this dosage to maintain the proper blood level of the chemical in milligrams per kilogram necessary to kill the ectoparasites.

Treating Premises. For effective control of fleas, the treatment of the animal should be supplemented by insecticidal applications to the premises. Special attention should be given to the resting places of the animal, where the eggs, larvae, pupae and adults are most abundant. Flea infestations may be greatest in dog kennels and bedding, rugs, under porches and similar resting places. Where possible, the animal bedding should be burned or laundered in hot, soapy water. A vacuum cleaner may be used to remove accumulations of lint and dust that contain flea larvae and pupae. Then the infested premises may be treated with a residual insecticide such as 0.5 to 1 percent lindane, 0.5 percent dieldrin, or 5 to 10 percent DDT solutions or emulsions at a rate of about 1 gallon per 1,000 square feet of floor surface. These materials are useful if resistance is not a problem. Where resistance to chlorinated hydrocarbon insecticides occurs, the organic phosphates may be used including 2 percent malathion or ronnel or 0.5 percent Diazinon. In difficult situations in kennels, runways, or basements with large amounts of rubbish or other material the application of 0.2 percent sprays of DDVP may be effective because of the fumigant action of this organic phosphorus insecticide. A number of factors will influence the choice of material and type of formulation to be used for indoor applications, particularly odor, fire hazard, possibility of staining, and use of the treated area. The sprays of choice are DDT, and, in case of resistant fleas, malathion or ronnel.

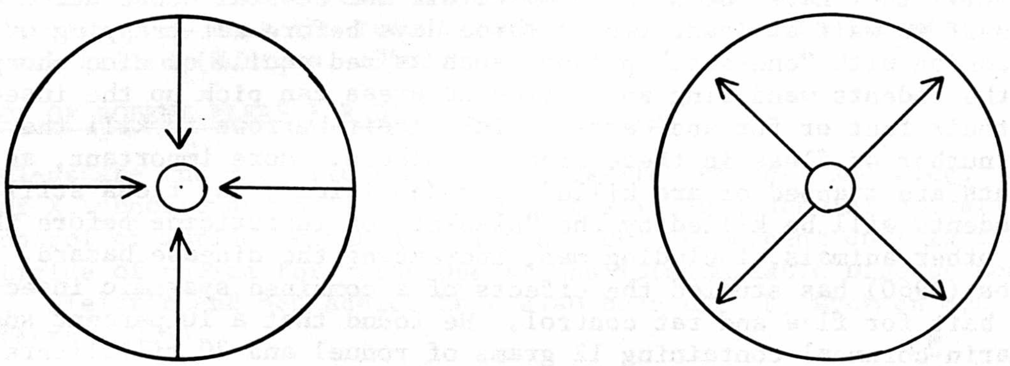
Dusts may also be used in controlling fleas inside buildings, particularly animal boxes or bedding, basements, and other situations where the whitish discoloration from powders is not objectionable. Dusts are frequently blown under porches, the crawl-space under homes, garages, and outbuildings. Five to 10 percent DDT dust is usually the insecticide of choice with 2 to 5 percent malathion dust if resistance is clear-cut.

In many places in the United States, particularly the South and West, yard infestations of fleas often are a real problem. Sanitation is just as important in flea control as in other fields of vector control. Animal manure and debris should be removed from pens and yards where fleas may be developing.

For insecticidal treatment of lawns and yards, dusts or suspensions are frequently used in preference to emulsions or solutions. Wettable powders and dusts are safe on shrubbery and grass and have a long residual action, but they leave a light-colored deposit. The dusts are frequently twice as strong as the sprays. Emulsions containing these insecticides may be used in yards, if the operator is certain that the emulsions being used will not harm the plants. Some of the auxiliary solvents used in preparing emulsion concentrates will "burn" foliage or grass. The use of solutions on vegetation is even more dangerous since many of the petroleum solvents are known to be phytotoxic. Care should be taken not to release sprays at high pressure close to foliage since this may also damage vegetation. Any soil or lawn areas that require treatment should be very thoroughly soaked.

CONTROL OF DISEASES TRANSMITTED BY RODENT FLEAS

Control of Urban Outbreaks. Fleas are the most important vectors of plague and murine typhus. Outbreaks of both diseases have been controlled in the past by rat-killing, rat-proofing, and improved sanitation, but real progress in the control of these diseases was not achieved until the mid-1940's with the advent of DDT and the anticoagulant rodenticides. In the early campaigns, control measures started outside the infested area and worked towards the suspected center of infection. Today, control operations are started at the suspected focus and work outwards.



Between 1900 and 1945, control programs for plague and murine typhus started at the periphery and worked toward the suspected center of infection, using rat-killing, burrow gassing, rodent stoppage, and improved sanitation.

Today, control programs start at the suspected focus of infection and work outwards with emphasis on residual insecticides and anticoagulant rodenticides, plus rat-trapping, rodent stoppage, and improved sanitation.

Figure 7.8 Contrasting concepts of rodent-flea-borne disease control.

In controlling an epidemic of plague or murine typhus, the following sequence of control operations has worked in a number of areas:

1. Surveys to determine extent and intensity of problem;
2. Application of residual insecticides such as DDT, dieldrin, or heptachlor to kill the infected fleas, particularly the oriental rat flea;
3. Use of anticoagulant rodenticides such as warfarin, Pival, or fumarin;
4. Rat trapping, poisoning with "one-shot" rodenticides such as red squill, or zinc phosphide, or burrow gassing, see Bjornson and Wright (1960);
5. Improved general sanitation to keep rodent populations at the lowest possible level, paying particular attention to refuse storage, collection and disposal, and harborage elimination;
6. Rodent stoppage, or rat-proofing; and
7. Continued surveys and maintenance to prevent build-up of disease potentials.

The application of residual insecticides at the suspected focus of infestation at the start of control activities places emphasis on killing the infected fleas as quickly as possible. The anticoagulant rodenticides are also distributed on the first day because these compounds do not kill rodents until they have eaten these materials for several consecutive days. It is wisest to wait at least two or three days before rat-trapping or area poisoning with "one-shot" poisons such as red squill or zinc phosphide so that the rodents wandering about treated areas can pick up the insecticide on their feet or fur and carry it into their burrows to kill the greatest number of fleas in these breeding places. More important, as the rodents are trapped or are killed by rodenticides, any fleas still on the rodents will be killed by the "blanket" of insecticide before they can bite other animals, including man, increasing the disease hazard. Bennington (1960) has studied the effects of a combined systemic insecticide and bait for flea and rat control. He found that a 10 percent sugar, 1:49 fumarin-cornmeal containing 12 grams of ronnel and 20 milliliters of liquid smoke per pound was attractive to rats, killed oriental rat fleas before the rats died in a feeding period of 5 or more days and resisted stored food pests.

General sanitation should be improved as quickly as flea control is achieved. Men working in the area should be vaccinated against plague or murine typhus and wear flea-proof clothing which has been treated with repellents such as M-1960 or conventional repellents. The more time-consuming work of rodent stoppage should not be started until the danger of contracting these diseases is reduced.

Control of Rural Outbreaks. The control of wild or commensal rodents which serve as a reservoir of these diseases, and of their ectoparasites, is difficult, expensive, time-consuming, and often meets with public apathy or disapproval. Love and Smith (1960) reported on murine typhus control activities in southwestern Georgia from 1945 to 1957. Although there was a great reduction in the number of rat fleas, rats, and particularly rats with murine typhus infections, complete eradication of rat fleas and rats was not achieved and reinfestations did occur. A new approach to the problem of rodent-flea-borne disease control has been tested by Barnes and Kartman (1960) using insecticide-bait boxes.

The bait-boxes were made of a floorboard (½ inch thick, 12 inches long, and 8 inches wide) covered by a metal inverted U-shaped roof. The bait pans, made from sardine tins, held about 100 grams of rolled oats, and the 10 percent DDT powder is placed at each end of the baseboard. They were used to control chipmunk and ground squirrel fleas in the Sierra Nevada Mountains of California, following similar trials with bait-boxes in Hawaii to control the plague vectors Xenopsylla cheopis and X. vexabilis hawaiiensis. The bait-box stations reduced fleas strikingly within 24 hours but very little residual control was obtained. A special feature of this method is that the rodent conveys insecticide to its nest where fleas are killed (Kartman, 1958).

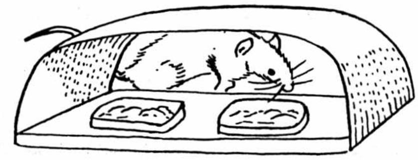


Figure 7.9 Insecticide bait-box for sylvatic plague control

CONTROL OF RODENT FLEAS FOR DISEASE PREVENTION

Fleas are the most important ectoparasites of rats and mice. Control of X. cheopis and other flea parasites is an essential operation in the control of murine typhus and plague. DDT 10 percent dust is the insecticide of choice for these operations (Communicable Disease Center, 1949). Dieldrin and heptachlor have also been used by Ryckman and co-workers (1954).

Burrow and harborage dusting: DDT dust is applied to rat burrows, holes in floors and walls, and enclosed spaces that may serve for rat harborage. It is especially important to treat spaces between double walls and floors and under merchandise where there are rat entries, because the danger of disease spread from rodent to man is most severe in buildings. The dust should be blown in so as to cover the entire surface with a light film.

Patch dusting: Dust patches consist of a layer of 10 percent DDT dust around a rat hole, entryway, burrow, or along a rat run that is in use. The thickness of the patch should depend upon the amount of rat travel evidenced by the presence of rat droppings and footprints. It may vary from a thin film to a patch 1/4 to 3/8" thick. Rat entries should be dusted thoroughly and an area of 6 to 8 inches radius treated around each entry. A runway patch is about 6 inches wide by 18 inches long placed on the narrowest part of the runway. Patches on stairways should completely cover two adjacent stair treads. When parasites of

TABLE 7.3

INSECTICIDES FOR FLEA CONTROL
(Percentage Concentration)

INSECTICIDE	DUSTS FOR ANIMALS		PREMISE TREATMENTS		RODENT FLEA CONTROL OUTDOORS
			Indoors	Outdoors	
	Cats & Pups	Dogs	Oil solutions or emulsions	Emulsions or wettable powder	Dusts
INSECTICIDES OF VEGETABLE ORIGIN					
*ROTENONE	*1	*1			
*PYRETHRUM	*1	*1			
Pyrethrum plus Synergist	0.2	0.2			
CHLORINATED HYDROCARBONS					
Methoxychlor	1-2				
*DDT	No	1	*5	*5	*5-10
Benzene Hexachloride	No	2-5	2-5	2-5	3- 5
Lindane	No	1	*0.5	1	
Chlordane	No	2-5	2	2	2- 5
Heptachlor	No	No			
Dieldrin	No	No	.5	0.5	2
Aldrin	No	No	No	No	2.5
ORGANIC PHOSPHATE INSECTICIDES					
*MALATHION	4	*4	2	2	
Diazinon	No	No	0.5	0.5	
Dipterex	No	No		1	
Ronnel			1%	1%	1%

*Insecticide of Choice

roof rats are to be controlled, dust alternate spaces between rafters on overhead "swings." Rat swing marks are usually detected by their dark and glossy appearance due to the fact that the rat rubs oil from its fur while swinging beneath rafters or traveling along a plate. Dust patches should be placed near feeding, watering, and harboring places of rats and other locations frequented by these rodents.

Amount of dust: A complete dust treatment is important in rat ectoparasite control. An average business establishment requires about 4 pounds of dust, whereas rural premises require about 2 pounds and urban residential premises about 1 pound.

Frequency of dusting: Ectoparasite dust applications should give good control up to 4 to 6 months after dusting, making it advisable to apply 2 dustings during the warm months of the year in the south. Only one application per year is customarily applied in the north. A single dusting in April, May, or June should suffice in the northern part of the murine typhus belt.

Equipment: The "Cyanogas" foot pump is useful for treating rat burrows and harborage. One model holds 5 pounds of dust. A 3-foot hose is provided to reach out-of-the-way rat holes. This piece of equipment does double duty, as it may be used for DDT dusting, or for applying calcium cyanide dust which will kill both rat and ectoparasite. Cyanide dust must under no circumstances be used within or beneath occupied buildings.

The plunger-type garden duster with a 3-pound insecticide chamber is very convenient for most rodent ectoparasite operations. It is a light piece of equipment easily obtained in most cities, and is fast in operation. Before using this duster it is necessary to remove part of the delivery tube and the bowl or deflector at the end of the tube, as the tips are required only for dusting the underside of foliage in garden dusting. A straight tube is more suitable for rodent ectoparasite control. A cylindrical hand duster is suitable for both space and patch dusting. When the delivery tube is in the upper position, it is completely submerged in the DDT dust, and a very heavy application results.

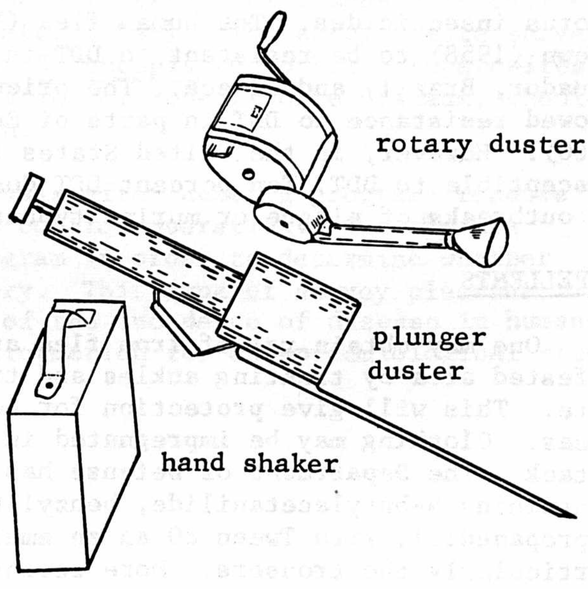


Figure 7.10 Equipment for rodent flea control

Rotary dusters are suitable for treating large enclosed or partially enclosed areas such as attics and spaces under buildings. These dusters generate a heavy blast of air that will blow the dust considerable distances. The rotary dusters and the diaphragm dusters serve a similar purpose, although the latter type of equipment is not always available on the open market.

Shaker cans are used to advantage when more elaborate equipment is not available. A 1-gallon rectangular shaker may be made out of a turpentine can or similar container. The end is cut out and a screen substituted. Some shakers have a hardware cloth screen plus a 16-mesh screen to close the end. A handle may be fastened on the side of the can. Small shaker cans may be made out of cylindrical containers such as mailing tubes. The top can be punctured with many nail holes and a handle mounted on the container in order that it may be used for treating overhead beams and rafters. If no equipment is available, dust may be compacted in the hand and cast into burrows and over runways.

RESISTANCE TO INSECTICIDES IN FLEAS

Although it is difficult to demonstrate in carefully-controlled laboratory tests that fleas are resistant to insecticides, many careful workers (Communicable Disease Center, 1961; Brown, 1958) believe that it is more difficult to kill cat and dog fleas (*Ctenocephalides felis* and *C. canis*) with the chlorinated hydrocarbon insecticides such as DDT, chlordane, and dieldrin at the present time than it was when these insecticides were first used in the late 1940's and early 1950's. This is sometimes called "practical resistance" since infestations of these same fleas can be controlled by the use of organic phosphorus insecticides. The human flea (*Pulex irritans*) was reported by Brown (1958) to be resistant to DDT in many countries including Peru, Ecuador, Brazil, and Greece. The oriental rat flea (*Xenopsylla cheopis*) showed resistance to DDT in parts of Ecuador and India (Patel *et al.*, 1960). However, in the United States the oriental rat flea is still susceptible to DDT. Ten percent DDT dust is the insecticide of choice if outbreaks of plague or murine typhus should occur in this country.

REPELLENTS

One may obtain relief from flea attack when going into a heavily infested area by treating ankles and trouser legs with dimethyl phthalate. This will give protection for several hours against cat and dog fleas. Clothing may be impregnated in benzyl benzoate to prevent flea attack. The Department of Defense has recommended the use of M-1960 containing N-butylacetanilide, benzyl benzoate, and 2-butyl-2-ethyl-1, 3-propanediol, with Tween 80 as an emulsifier for clothing treatment - particularly the trousers. More recently diethyl-toluamide, sold commercially as OFF or DET, has shown great promise as a flea repellent. After an area has been dusted, these materials are no longer necessary. DDT or chlordane dusts prevent biting almost immediately, althouth 3 or 4 hours may be required for complete mortality of dusted fleas.

RODENT ECTOPARASITE SURVEYS

Purpose of Evaluation Surveys: Evaluation surveys are essential operations in the control of flea-borne diseases. These surveys may involve sampling of population of rats in order to learn the relative abundance of Norway and roof rats in the locality, particularly animals infected with plague or murine typhus. Another type of survey measures the ectoparasite population of rats to determine whether or not the oriental rat flea is prevalent. It is also possible to determine the incidence of murine typhus in the rodent reservoir by means of complement fixation or Weil-Felix tests of rat blood, and of plague by culturing certain tissues such as the spleen. The above types of information are generally recorded for each lot of rats trapped.

Survey Methods: The usual survey method for determining the number of parasites per rat and the percentage of rats infested by the oriental rat flea requires the trapping of live rats at numerous points in the survey city. The rats are trapped in #0 steel traps and placed immediately in individual cloth bags to prevent the escape of fleas and other ectoparasites. They are brought to the laboratory in these bags, which are labeled to show the date, trapper, species, and sex of rat, locality, and other information. The rats are anaesthetized and combed with a fine-toothed comb in order that the parasites may be collected in a large white pan. These parasites are later identified, counted, and recorded along with the rat number and other information on the trapped rat. It is then possible to determine the number of *X. cheopis* per rat and the percentage of rats infested by *X. cheopis*. This method and other survey methods are discussed in the manual, "Rat-Borne Disease Prevention and Control", Communicable Disease Center (1949). The ectoparasite survey indicates the degree of infestation by *X. cheopis* and other ectoparasites, hence the potential danger of transmission of rodent-borne disease, should it be present in the rodent population.

Surveys made before and at intervals after dusting programs measure the effectiveness and duration of the control operation. Surveys are made in planning a vector control program in order to determine whether or not dusting operations are necessary. This type of survey plus the information obtained from tabulation of the incidence of disease in humans and domestic rats, furnishes basic information for an epidemiological study of the disease.

AUDIOVISUAL AIDS

Films and filmstrips listed in this training guide are available for free, short-term loan within the United States, for loan to State and Local Health Departments, Federal agencies, medical schools, hospitals, professional organizations, and other groups engaged in public health activities for public service showing. Please indicate exact dates that films are to be used and allow ample time for shipment. Requests should be addressed to:

Communicable Disease Center
Atlanta 22, Georgia

Attn: Audiovisual

COLLECTION AND SHIPMENT OF INSECTS. (F-256). USPHS, CDC, 1957. Filmstrip, color, sound, 35 mm., 9½ minutes.

EPIDEMIOLOGY OF MURINE TYPHUS. (4-049.1). USPHS, CDC, 1953. Motion picture, black and white, sound, 16 mm., 18 minutes.

IDENTIFICATION OF SOME COMMON FLEAS. (F-101). USPHS, CDC, 1952. Filmstrip, 59 frames, black and white, 35 mm. with 16-inch disc, 33 1/3 rpm., 13 minutes.

RAT ECTOPARASITE CONTROL. (M-37.1g). USPHS, CDC, 1954. Motion picture, black and white, sound, 16 mm., 8 minutes.

THE RAT PROBLEM. (M-37.1a). USPHS, CDC, 1954. Motion picture, black and white, sound, 16 mm., 16 minutes.

PLAGUE IN SYLVATIC AREAS. (M-440). USPHS, CDC, 1961. Motion picture, color, sound, 16 mm., 25 minutes.

PLAGUE CONTROL. U. S. Department of the Navy, 1945. Motion picture, color, sound, 16 mm., 21 minutes. One copy in CDC Film Library for limited use. Also available from the Audiovisual Training Section, Bureau of Medicine and Surgery, Dept. of Navy, Washington 25, D. C.

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