# SPOTTED FEVER

HARRY B. WEINBURGH

1966

4th Printing 1967

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
BUREAU OF DISEASE PREVENTION AND ENVIRONMENTAL CONTROL
NATIONAL
U.S COMMUNICABLE DISEASE CENTER, Atlanta
Atlanta, Georgia 30333

## CONTENTS

## INTRODUCTION

Spotted fever is a disease of wild mammals, man, and other animals. The disease is caused by one of the rickettsiae, Rickettsia rickettsi, and is transmitted by certain species of hard ticks. Rickettsiae are considered an order of bacteria, of which they are among the smallest. Rickettsiae, most of which are obligate intracellular parasites, are unable to reproduce when separated from their host tissues (the rickettsiae causing Q fever are exceptions). The rickettsiae of spotted fever multiply in the endothelial cells of arterioles, venules, and capillaries throughout the body. Infection of spotted fever in man is characterized as an acute febrile illness with sudden onset, a skin rash, high fever, and is one of the most severe of infectious diseases in areas with highly virulent strains.

Human cases have been reported, in recent years, in 46 of the States of the United States. Spotted fever also occurs in Canada, Mexico, and South America. Human cases have occurred in all months of the year, but are more common in spring and early summer. Sixty-five percent (715 of 1,106) reported cases in the United States during the period 1960-64 occurred in the 10 Appalachian States (Alabama, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, South Carolina, Tennessee, Virginia, and West Virginia).

Fatality in untreated cases is about 20 percent; this varies, however, from 5 to 80 percent, depending upon the virulence of the strain of R. rickettsi in different locations. Specific treatment includes chlortetracycline, chloramphenicol, and oxytetracycline.

Laboratory diagnosis can be made by inoculation of guinea pigs with blood drawn from patients for rickettsial isolation, but is most commonly made by serological tests — the Weil-Felix test and the complement-fixation test.

The rickettsiae causing the disease are maintained in ticks and the animals on which they feed. Man is an accidental host. Humans contract the disease by being bitten by an infected tick. The incubation period is usually 4 to 8 days, with extremes of 2 to 12 days.

## HISTORY

Spotted fever has been known in Montana since 1872. The disease was named Rocky Mountain spotted fever to distinguish it from epidemic meningitis and typhus which were also sometimes called spotted fever. This disease was known to be present in two endemic areas in Montana — the Bitter Root Valley and environs, and in a limited area in Carbon County across the continental divide (Cooley, 1932).

The theory that a tick is the natural vector of spotted fever was first advanced in 1902 (Wilson and Chowning, 1902). The first proof of tick transmission of spotted fever was obtained by Drs. McCalla and Brerton of Boise, Idaho, in 1905 (Hunter and Bishopp, 1911).

The famous experiments of Ricketts were begun in 1906. These experiments proved that a female tick (Dermacentor andersoni) could transmit spotted fever. Experiments in 1907 showed that male ticks could transmit the disease as well as female ticks, and that one attack of spotted fever establishes a high degree of immunity to subsequent infection. Ticks collected in the field were found to be infected with rickettsia. Further experiments proved that rickettsia may be acquired and transmitted by the tick during any of the active stages, that some of the larvae of an infected female are infected, and that spotted fever is probably transmitted through the salivary secretion of the tick (Ricketts, 1906; Ricketts, 1907; Parker, Philips and Jellison, 1933).

Experiments by Moore showed that the minimum duration of feeding necessary for a tick to infect was 1-3/4 hours, the average time required was about 10 hours, while 20 hours of feeding almost always proved infective. Maver found that spotted fever can be transmitted by nymphal D. variabilis infected as larvae, by adult D. parumapertus and by nymphs of Amblyomma americanum. Transmission by adult D. albipictus infected as nymphs was demonstrated by Ricketts (Ricketts, 1911).

The etiological agent was described by Wolbach in 1919, who named it Dermacentroxenus rickettsi in honor of Dr. Ricketts, who had made great contributions to our knowledge of both spotted fever and typhus fever, and who lost his life in the conduct of investigations in Mexico (Wolbach, 1919). The several rickettsioses transmitted by arthropods are caused by infectious agents known as rickettsiae; hence, the casual agent of spotted fever is generally referred to as Rickettsia rickettsi (Wolbach).

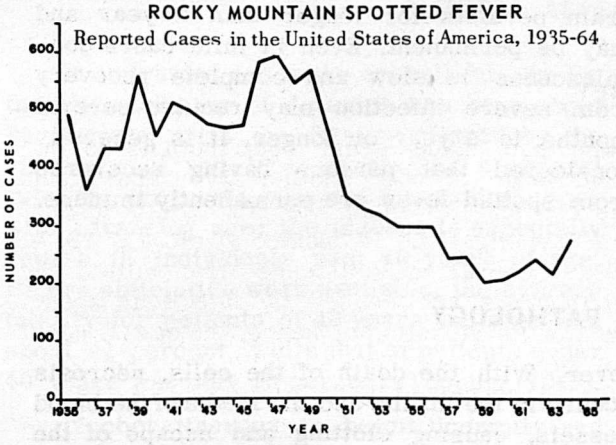
The rabbit tick, Haemaphysalis leporispalustris, was found to be the vector of spotted fever from rabbit to rabbit (Parker, 1923). While the rabbit tick rarely bites man, it is important indirectly in that it is a potential vector under natural conditions and is the only known vector that occurs in all parts of the United States.

Spotted fever was thought to be a relatively obscure disease confined to a limited portion of the northern Rocky Mountain region until 1931. Cases of a typhus-like infection originating in rural sections of the eastern States, which had heretofore been diagnosed as endemic typhus, were found to be indistinguishable immunologically and clinically from Rocky Mountain spotted fever. The American dog tick, D. variabilis, was proved to be a vector of spotted fever in the eastern States in 1931 (Dyer, Badger, and Rumreich, 1931).

Three human cases of spotted fever occurred on Gardiner's Island, New York; two in 1912 and a third in 1931. Although spotted fever was suspected, since each patient had been bitten by a tick, the diagnosis of spotted fever was rejected because the tick species involved, D. variabilis, was not then known to be a vector of spotted fever (Davis, 1947).

The total number of spotted fever cases reported in the United States of America has declined from almost 600 cases annually in 1946 and 1947 to less than 300 cases annually in the period 1954 through 1964 (see Figure 1). The two important endemic foci at present are the Rocky Mountain States: Montana, Wyoming, Idaho, Oregon, Utah and Colorado; and the Appalachian States: Alabama, Georgia, Kentucky, Maryland, North Carolina, Pennsylvania, South Carolina, Tennessee, Virginia

Figure 1.
ROCKY MOUNTAIN SPOTTED FEVER
Reported Cases in the United States of America, 1935-64




and West Virginia. The number of cases in the West, especially Montana and Wyoming, began to decline around 1944, with 21 cases occurring in the western endemic States in 1964. The reason for this decline in the western endemic States is speculative, but is probably due to the use of antibiotic drugs during the pre-eruptive stages of the illness. The residents of these States are aware that spotted fever is present in the ticks and take precautions. By way of contrast, the cases of spotted fever in the States of the Appalachian region accounted for about two thirds (715 of 1,106) of the spotted fever cases reported in the United States during the period 1960-64.

## CLINICAL ASPECTS: DESCRIPTION

Spotted fever is one of the most severe of all infectious diseases. Attacks range from mild ambulatory and abortive forms to rapidly terminating fatal attacks. In vaccinated persons and young children, attacks are usually mild and atypical.

In nonvaccinated adults, the incubation period of the disease is usually 4 to 8 days but may show extremes of 2 to 12 days. The manifestations of the onset of the disease are listlessness, malaise, headache, loss of appetite, and a chilling sensation. Onset of the disease is usually abrupt. It is manifested by a definite chill, pronounced headache, severe aches and pains in the muscles, bones, and joints, profound prostration and a rapidly rising fever that continues to mount into the second week. Muscle and joint pains are marked, and in severe form, nosebleed may occur early.

A distinct rash usually appears on the third day of the disease. The early rash may resemble the slight mottling seen in measles. The rash appears first on the ankles and wrists, and spreads to the legs, arms, and chest. The lesions are small discolored spots not elevated above the skin at first but later become raised above the skin. The lesions are more pronounced on the extremities. The palms and soles and at times even the face and scalp become involved. The extension of the rash usually becomes complete within two or three days so that the entire body is covered. In severe cases, the lesions run together, become deep red or purplish in color and often necrotic. Masses of such areas may involve the entire body. The eruption gradually fades as the patients recover, with the process taking much longer in more severe cases of the disease.

As the disease progresses, mental confusion, restlessness, dulling of the senses and lethargy progressing to coma may be noted. Muscular twitching, fibrillary tremors, purposeless movements and abnormal neurological signs may occur. Once fever has appeared, the temperature rises quickly. Fevers of 104°F. to 105°F. are common. Remissions of 1° to 3° F. may be observed in morning temperatures. The maximum temperature will be reached, usually, during the second week of the disease, anywhere from the seventh to the fourteenth day. With recovery the temperature usually falls slowly after a febrile period varying from 2 to 3 weeks. Mild cases may become afebrile before the end of the second week of the disease. At the onset and early in the course of the disease the pulse is full and strong, averaging approximately 90 beats per minute. When myocardial weakening occurs in severe cases as a result of toxemia, a loss of volume and strength of the pulse occurs. The blood pressure falls as a result of myocardial involvement and vascular collapse, and the first heart sound becomes muffled and indistinct. The pulmonary edema which then appears often indicates a fatal termination within a few hours. The respirations, at first, are normal or but slightly increased. They accelerate in severe cases. The respiration rates often indicate the development of pneumonia. Terminal temperatures of 108°F.,

pulse rates of 140 to 160 and respiration rates of 40 to 60 per minute are not uncommon. A short incubation period, high pulse rate, severe mental changes, edema, absolute depression or deficient secretion of urine, a petechial rash, and pneumonia are poor prognostic signs (Cox, 1959; Harrel, 1949).

In some patients the acute changes clear up with convalescence, but in others the damage to blood vessels, central nervous system, and brain persists for longer than a year and may be permanent. Even in mild cases convalescence is slow and complete recovery from severe infection may require several months to a year or longer. It is generally considered that persons having recovered from spotted fever are permanently immune.

## CLINICAL ASPECTS: PATHOLOGY

Spotted fever is essentially a specific generalized intracellular infection of small peripheral blood vessels. In untreated patients, the rickettsiae circulate in the blood during the first week and usually part of the second week after infection. The rickettsiae first invade the nuclei of the capillary endothelial cells, where they multiply and destroy the cells. The lesions then extend along the intima into arterioles, where smooth muscle cells of the media are also invaded and destroyed. The destruction of smooth muscle cells is a most distinctive feature of spotted fever. With the death of the cells, necrosis occurs in the intima and the media of the blood vessels, causing clotting and escape of the blood. Small areas of coagulation necrosis are then formed, chiefly in the skin, the subcutaneous tissues and the central nervous system. In the central nervous system, areas of demyelination may be found adjacent to or removed from the vascular lesions. Spotted fever produces greater damage to the skin, the subcutaneous tissues and the brain than does any other rickettsial disease (Cox, 1959).

## CLINICAL ASPECTS: TREATMENT

Spotted fever may present a difficult therapeutic problem. If the patient has a history of tick exposure and is moderately to severely ill, antibiotics should be started immediately. Otherwise, therapy consists of merely relieving the symptoms until diagnosis is established by the appearance of the rash.

The principles for the management of spotted fever are specific chemotherapy and supportive care. Attention to both is mandatory for the seriously ill patient first seen late in the disease. For a moderately ill patient seen during the first week of disease, supportive therapy may be less energetic and specific antibiotic therapy usually suffices.

Antibiotic therapy can be started when the rash appears; its value is progressively diminished after the first week of the disease. The antibiotics available do not kill the rickettsiae but merely suppress the growth of the rickettsiae. The antibiotics prevent further damage caused by the organism but do not repair damage that has already occurred.

Aspirin and all sulfonamides are definitely contraindicated throughout the course of spotted fever, since their administration to human beings has increased the severity of the illness. Penicillin and streptomycin have no value.

The antibiotics of choice are chloramphenicol, chlortetracycline, oxytetracycline, and tetracycline. Each antibiotic is available for oral, intravenous, and intramuscular use. The intramuscular route is the least preferred. There is a characteristic period required for the broad spectrum antibiotics to elicit a clinical response — about one day in spotted fever.

Frequent turning of the patient will relieve pressure on prominent bony parts of the body, will prevent gangrene of the skin, and will also delay the development of pneumonia. The administration of a properly nutritious diet through frequent feeding is important, since malnutrition frequently develops in seriously ill patients.

Pneumonia is a complication frequently noted in the course of spotted fever. The pneumonitis responds to the antibiotic therapy. Oxygen may be helpful.

None of the antibiotics is advised for the prevention of the disease after a tick bite has occurred.

## CLINICAL ASPECTS: PROGNOSIS

In untreated cases the overall fatality for the United States of America has been about 20 percent, with the fatality altered by the virulence of the local strain. As a general rule, the prognosis becomes increasingly poor with advancing age; the disease is especially severe in individuals past 40 years of age. Before antibiotics were available, the average fatality for patients of 40 years and over was about 41 percent, while that of patients under 40 years was only 13 percent (Topping, 1941).

If chemotherapy is begun promptly and continued for several days past the return of the temperature to normal, recovery is usually complete. Convalescence may be slow, and complete recovery may not occur for weeks, months, or as long as a year, even in a relatively mild infection. The host may continue to harbor living rickettsiae for considerable periods of time after recovery (Harrel, 1949).

It has long been the popular conception that spotted fever is a more highly virulent, and, therefore, a more fatal disease in the West than in the East. Reported observations from laboratories lent support to this belief because the rickettsiae isolated and reported in the West were more pathogenic for guinea pigs than those isolated in the East. With the discovery in the early 1940's that highly virulent and mild strains of spotted fever rickettsiae existed in both areas, a study was made of human fatality rates in two western States, Idaho and Montana, and in two eastern States, Maryland and Virginia. During the period 1930-39, Idaho and Montana reported 747 cases, with a crude fatality rate of 28.1 percent, while Maryland and Virginia reported 661 cases, with a fatality rate of 18.4 percent. In the two western States, 50.2 percent (375) of the total cases occurred in persons aged 40 years or over, 35.3 percent (264) in the age group 15-39 years, and only 14.4 percent (108) in persons under 15 years. In the two eastern States this age distribution is almost reversed, with the largest number of cases, 46.8 percent (310), occurring in persons under 15 years of age; 28.5 percent (189) occurred in the age group 15-39 years; and only 24.5 percent (162) in the group aged 40 or over (Topping, 1941).

Table 1.—*Spotted fever. Cases occurring in certain western and eastern States, by age and fatality rate*

| State | Number of cases | Number of deaths | Fatality rate | Under 15 years | | | | 15-39 years | | | | 40 and over | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | Cases | Percent of total | Deaths | Fatality rate | Cases | Percent of total | Deaths | Fatality rate | Cases | Percent of total | Deaths | Fatality rate |
| West: | | | | | | | | | | | | | | | |
| Idaho | 293 | 101 | 34.4 | 27 | 9.2 | 7 | 25.9 | 108 | 36.8 | 22 | 20.3 | 158 | 53.9 | 72 | 45.5 |
| Montana | 454 | 109 | 24.0 | 81 | 17.8 | 6 | 7.4 | 156 | 34.3 | 18 | 11.5 | 217 | 47.8 | 85 | 39.1 |
| Total | 747 | 210 | 28.1 | 108 | 14.4 | 13 | 12.0 | 264 | 35.3 | 40 | 15.1 | 375 | 50.2 | 157 | 41.8 |
| East: | | | | | | | | | | | | | | | |
| Maryland | 330 | 66 | 20.0 | 155 | 46.9 | 19 | 12.2 | 85 | 25.7 | 13 | 15.2 | 90 | 27.2 | 34 | 37.7 |
| Virginia | 331 | 56 | 16.9 | 155 | 46.8 | 21 | 13.5 | 104 | 31.4 | 8 | 7.6 | 72 | 21.7 | 27 | 37.5 |
| Total | 661 | 122 | 18.4 | 310 | 46.8 | 40 | 12.9 | 189 | 28.5 | 21 | 11.1 | 162 | 24.5 | 61 | 37.6 |

Note: All cases and deaths as reported to the State Health Officer; Montana, Idaho, and Maryland, 1930-39, inclusive; Virginia, 1933-39, inclusive.

Table 2.—*Spotted fever. Cases occurring in certain western and eastern States, by sex and age*

| Sex | Number of cases | Percent | Number of deaths | Rate | Under 15 years | | | | 15-39 years | | | | 40 and over | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | Cases | Percent of total | Deaths | Fatality rate | Cases | Percent of total | Deaths | Fatality rate | Cases | Percent of total | Deaths | Fatality rate |
| West: | | | | | | | | | | | | | | | | |
| Male | 624 | 83.5 | 182 | 29.1 | 55 | 7.3 | 5 | 9.0 | 239 | 31.9 | 32 | 13.3 | 330 | 44.1 | 145 | 43.9 |
| Female | 123 | 16.5 | 28 | 22.7 | 53 | 7.0 | 8 | 15.0 | 25 | 3.3 | 8 | 32.0 | 45 | 6.0 | 12 | 26.6 |
| Total | 747 | .... | 210 | 28.1 | 108 | 14.4 | 13 | 12.0 | 264 | 35.3 | 40 | 15.1 | 375 | 50.2 | 157 | 41.8 |
| East: | | | | | | | | | | | | | | | | |
| Male | 401 | 60.6 | 83 | 20.6 | 170 | 25.7 | 23 | 13.5 | 124 | 18.7 | 17 | 13.7 | 107 | 16.1 | 43 | 40.1 |
| Female | 260 | 39.4 | 39 | 15.0 | 140 | 21.2 | 17 | 12.1 | 65 | 9.8 | 4 | 6.1 | 55 | 8.3 | 18 | 32.7 |
| Total | 661 | .... | 122 | 18.4 | 310 | 46.8 | 40 | 12.9 | 189 | 28.5 | 21 | 11.1 | 162 | 24.5 | 61 | 37.6 |

When the fatality rates for the two areas are compared on the basis of age, it is seen that there is very little difference. For the age group under 15 years the fatality rate was 12.9 percent in the East and 12 percent in the West; for the age group 15-39 years, 11.1 percent in the East and 15.5 percent in the West; and for the group aged 40 and over, 37.6 percent in the East and 41.8 percent in the West. No significant difference in these rates was found for the various age groups. It is apparent, however, that there were important differences in the fatality rates for the groups aged 40 years and over in both areas as compared to the rates for the younger persons. Tables 1 and 2 (from Topping, 1941) show the age and sex distribution in the two areas, as well as the fatality rates. It will be noted that there are proportionately more females infected in the East than in the West (Topping, 1941).

Since antibiotic treatment became available, the overall fatality rate has declined from 20 percent to about 6 percent, as shown in table 3.

Table 3.—*Spotted fever. Reported cases and deaths by year*

| Year | Cases | Deaths | Case fatality per 100 cases |
|---|---|---|---|
| 1949 | 570 | 36 | 6.3 |
| 1950 | 464 | 31 | 6.7 |
| 1951 | 347 | 26 | 7.5 |
| 1952 | 327 | 20 | 6.1 |
| 1953 | 313 | 21 | 6.7 |
| 1954 | 294 | 10 | 3.4 |
| 1955 | 295 | 8 | 2.7 |
| 1956 | 293 | 16 | 5.5 |
| 1957 | 240 | 18 | 7.5 |
| 1958 | 243 | 14 | 5.8 |
| 1959 | 199 | 10 | 5.0 |
| 1960 | 204 | 11 | 5.4 |
| 1961 | 219 | 11 | 5.0 |
| 1962 | 240 | 12 | 5.0 |

Total = 4,248 cases with 244 deaths for a fatality rate of 5.7 deaths/100 cases.

## CLINICAL ASPECTS: IMMUNOLOGY

Inborn resistance to spotted fever has not been detected. An attack of spotted fever produces effective immunity, but later cases can occur. Recovery from spotted fever does not confer cross immunity against other rickettsial infections which occur in the United States of America.

Vaccination within the year in which infection is acquired eliminates mortality, and reduces clinical severity. It is questionable that the vaccine is of value after the infection has been acquired; it is of no value after the onset of illness. Its use is recommended for persons with known exposure to tick vectors of spotted fever and for certain laboratory personnel.

## ETIOLOGY: PATHOGEN

Rickettsiae are small, gram-negative, pleomorphic, coccobacillary microorganisms that measure 0.3–0.5 microns in diameter. They are nonmotile, nonsporeforming, and nonfilterable agents visible with the light microscope. Binary fission has been observed under electron microscopy.

Rickettsia rickettsi in yolk sac are best stained by the Giminez stain. In mammalian tissue they may be stained equally well by the Macchiavello or Giesma stain (Giminez, 1964).

All attempts to cultivate R. rickettsi on artificial media have been unsuccessful, but it grows readily in tissue cultures and in the chorioallantois and yolk sac of developing chick embryo. The striking feature of R. rickettsi in tissue culture is its capability of invading the cell nuclei where it grows in compact clusters; often the entire nucleus becomes distended with organisms.

Spotted fever rickettsiae are killed in a few minutes by exposure to moist heat at 50°C. or to chemical agents, and in a few hours by dessication at room temperatures.

When a hard tick ingests R. rickettsi, there is a period during which the organisms invade the tick tissues. The tick is unable to transmit the rickettsiae through its bite until the invasion has established rickettsiae in the tick's salivary glands. A normal tick was fed on an infected host just long enough to insure ingestion of the rickettsiae. This tick was then transferred to a susceptible host. The tick's feeding was thus interrupted but essentially continuous. The tick was unable to infect the new host for a period of from 9 to 12 days. These ticks, which are unable to transmit the infection by biting during this period of rickettsial invasion, nevertheless cause infection if ground then injected into susceptible animals. Infection is not normally transmitted by the same stage of the tick that acquires it: larval, nymphal, and female adult ticks usually complete their engorgement during a single uninterrupted feeding on a single host. The rickettsiae begin invading the tick tissues when ingested and are now highly virulent and produce typical infections in laboratory animals. After the tick has completed engorging itself with blood and has dropped off the host, however, the rickettsiae gradually become less virulent until they are of such low virulence that they do not produce disease symptoms when injected into laboratory animals (no feeding by quiescent, molting ticks) but rather have an immunizing effect. The rickettsiae, however, are capable of infecting fertile chick eggs at this stage. Sometimes the rickettsiae may entirely lose their infectious quality and persist in a nonsymptom-producing, nonimmunizing phase which can be demonstrated by the fluorescent antibody technique only. The rickettsiae pass the winter (in ticks) in these low-virulence phases.

When these ticks emerge from hibernation in the spring, the rickettsiae, when demonstrable, do not produce disease symptoms when injected into laboratory animals, but only produce an immunizing effect. If these ticks are subjected to incubation or allowed to ingest blood, however, the rickettsiae again regain their ability to produce disease symptoms when injected into laboratory animals. This transition from a low virulence hibernating phase to a highly virulent, symptom-producing phase following incubation or feeding is termed "reactivation" (Parker, 1933).

There appears to be four general strains of R. rickettsi which differ in their virulence to guinea pigs (and presumably to humans). These strains have been designated as strain R (highly virulent), strains S and T (mildly virulent), and strain U (nonvirulent), although there seems to be some doubt that strain U is R. rickettsi. Guinea pigs injected with any one strain develop immunity to any of the other three strains. R. rickettsi when grown in the yolk sac of the developing chick embryo produces a substance toxic for mice: this "toxin" is neutralized by antiserum (Bell and Pickens, 1953).

## ETIOLOGY: DIAGNOSIS

Spotted fever is not an easily recognized infection. The very mild infections and the rapidly fulminating types are quite difficult to diagnose clinically. Furthermore, in areas where both spotted fever and murine typhus are present, an additional difficulty is encountered because of their marked clinical similarity. Spotted fever should be suspected during the tick season in cases of febrile disease that occur in those persons whose

occupation or habits expose them to ticks. Close examination may show the presence of a tick or an indurated area representing the site of a tick bite. The differential diagnosis is difficult, since it entails consideration of certain eruptive diseases, as well as other rickettsial and tick-borne diseases. Spotted fever rash may resemble that of measles, meningococcal meningitis, scarlet fever, typhoid fever and septicemic conditions as well as certain drug rashes. Measles is the disease most frequently confused with spotted fever (Rivers and Horsfall, 1959).

In the United States of America, the other rickettsial diseases likely to cause difficulty in diagnosis are rickettsialpox and murine typhus. Rickettsialpox is characterized by an initial lesion at the site of the mite bite. Murine typhus occurs mainly in the late summer and fall in the southern and southeastern States and is characterized by the development of a rash, first on the trunk and later on the extremities. The two tick-borne diseases which should be considered are Colorado tick fever and tularemia. There is usually no rash associated with Colorado tick fever. The development of an ulcer at the site of tick attachment, accompanied by enlargement of the regional lymph nodes, suggests tularemia (Rivers and Horsfall, 1959).

The isolation and identification of rickettsiae by inoculation of animals or chick embryo are too complex and uncertain for general laboratory use. Etiological diagnosis can be made by specific serologic reactions (complement-fixation) which are available in most State laboratories. When specific immunologic tests are to be used, specimens are obtained during the acute and convalescent stages. This method has the disadvantage that at least two weeks are required for the test, and, if specific antibiotic treatment has not been started by this time, the patient often becomes very seriously ill, and may die.

It has been the common practice to base diagnosis of spotted fever on clinical features, epidemiologic data (history of tick bite, or of crushing ticks while deticking dogs), and the nonspecific evidence offered by the Weil-Felix test.

The Weil-Felix test is helpful in establishing presumptive diagnosis in diseases caused by members of the typhus and spotted fever groups of rickettsiae. The typical responses obtained with suspensions of Proteus bacillus OX-19, OX-2, and OX-K strains and convalescent sera from patients with rickettsial diseases are given in Table 4.

The Weil-Felix response in spotted fever may be of several types — a high OX-19 and a low OX-2, or an elevation of both OX-19 and OX-2, or, occasionally, a low OX-19 and a high OX-2. Sera of patients with rickettsialpox or Q fever fail to agglutinate any of these organisms.

The Weil-Felix agglutinins may appear as early as the 5th or 6th day after onset of fever in those diseases in which the reaction becomes positive, and they are almost always positive by the 12th day. These antibodies generally reach their maximum in early convalescence and then decline rapidly to nondiagnostic levels in one to several months.

Table 4.—*Usual Weil-Felix agglutination reaction observed in rickettsial diseases*

| Disease | OX-19 | OX-2 | OX-K |
|---|---|---|---|
| Epidemic typhus | ++++ | + | 0 |
| Murine typhus | ++++ | + | 0 |
| Scrub typhus | 0 | 0 | +++ |
| Spotted fever group | ++++ | + | 0 |
| | + | ++++ | 0 |
| Rickettsialpox | 0 | 0 | 0 |
| Q fever | 0 | 0 | 0 |

A rise in antibody titer, demonstrated in a series of two or more sera, is essential for the diagnosis of rickettsial diseases when the Weil-Felix reaction is used. Interpretation of results on the basis of tests on a single serum is not justified unless the titer is high, that is, well above 1:160. The Weil-Felix reaction frequently fails to provide even presumptive evidence for separating spotted fever from murine typhus.

The specific serologic techniques of greatest importance in the diagnosis of rickettsial infections are the complement-fixation and agglutination tests that use rickettsial materials as antigens. Diagnostic complement-fixation procedures are available for each of the common rickettsial diseases. Group-specific antigens, which are available for differentiating infections caused by the epidemic-murine typhus group from those of the spotted fever-rickettsialpox group, are less expensive than the type-specific antigens, but they usually fail to provide exact identification of diseases resulting from rickettsiae

with common antigens such as R. prowazeki and R. mooseri or R. rickettsi, R. akari, and R. concori. In many geographical areas only one member of a related group of rickettsiae is present; here group-specific diagnostic antigens are adequate (Smadel and Jackson, 1964).

A four-fold or greater rise in C-F titer between acute and convalescent phase serum specimens is considered diagnostic. If an acute phase serum is not available, a specimen taken 4-6 weeks after onset and one taken 12-14 weeks after onset may reveal a decline in titer that has diagnostic significance. When only a single convalescent phase serum is available, significance is given to a titer greater than 1:160. In some cases, however, C-F antibodies have persisted in significant titer for many years.

Since the advent of specific antibiotic therapy for spotted fever, personnel in laboratories have experienced increasing difficulty in detecting clinical spotted fever by means of the C-F test. The Rocky Mountain Laboratory found that antibiotic therapy interferes with the development of C-F antibodies to a greater extent than with the production of Proteus agglutinins. This fact increases the diagnostic value of the Weil-Felix test. Caution should be observed in interpreting negative findings in C-F tests when the patient has received antibiotic therapy (Lackman and Gerloff, 1953).

The fluorescent antibody technique can be used to detect R. rickettsi in ticks. Laboratory Branch, CDC, is developing a F-A technique for detection of early infections while the rickettsiae are still present in the blood of humans.

## EPIDEMIOLOGY: GENERAL

Spotted fever is transmitted to man by the bite of an infected tick and by contamination of the skin with crushed tissues or feces of infected ticks.

In the United States, spotted fever is transmitted to man by three ticks: the Rocky Mountain wood tick, Dermacentor andersoni, in the Rocky Mountains; the American dog tick, D. variabilis, from east of the Rocky Mountains to the East Coast; and the lone star tick, Amblyomma americanum, in the south central part of the United States of America. The larvae and nymphs of D. andersoni and D. variabilis feed on small mammals, but not usually on man, while the adults feed on larger mammals and man; all three stages of A. americanum will feed on man and large mammals, notably deer, cattle, horses, and dogs; all are frequently present on the same host. This species shows little host preference.

The ticks act as the reservoir of spotted fever: R. rickettsi is transmitted from one generation to the next through the egg; and is passed from one stage to the next. This mechanism helps to maintain the infection in the ticks, and spreads the infection somewhat.

The rodents, rabbits, and hares upon which the different stages of the tick feed serve to spread the disease from infected ticks to uninfected ticks: these animals show a rickettsiasemia after being bitten by an infected tick and are able to infect uninfected ticks.

Usually less than one percent of the ticks in an area are infected — an infection rate among ticks as high as five percent is considered to be extremely high.

## EPIDEMIOLOGY: MAMMALS

Certain species of terrestrial mammals, particularly rodents, have long been suspected of being involved in the epidemiology of spotted fever because (1) they are essential hosts for the perpetuation of the ixodid ticks and (2) antibodies against spotted fever rickettsiae have been demonstrated in sera from some of these small animals. Although many isolations of R. rickettsi had been made from patients and ticks, no isolations of spotted fever rickettsiae were reported from a native wild mammal in the United States of America until 1954 when a strain of R. rickettsi was isolated from a meadow vole, Microtus pennsylvanicus, trapped in Virginia (Gould and Meisse, 1954). Isolations of R. rickettsi were made from a snowshoe rabbit, Lepus americanus, a golden-mantled ground squirrel, Citellus lateralis, and five yellow-pine chipmunks, Eutamias amoenus, trapped on the west side of the Bitter Root Valley, Montana, in 1961 (Burgdorfer, et. al., 1962).

In a recent study of the ecology of spotted fever in Virginia, isolations of R. rickettsi were made from an eastern cottontail, Sylvilagus floridanus, two meadow voles, M. pennsylvanicus, a white-footed mouse, Peromyscus leucopus, a cotton rat, Sigmodon hispidus, and an opossum, Didelphis virginiana (Dorer, et al., 1964).

Isolation of R. rickettsi from wild animals has been very difficult. Most of the animals from which the rickettsiae have been isolated have been young animals. The detection of antibodies against R. rickettsi has been much more successful. Antibodies against spotted fever have been detected in the sera of most of the mammals which serve as hosts of the tick vectors, as shown in Table 5 (Anonymous, 1960; Dorer, et al., 1964).

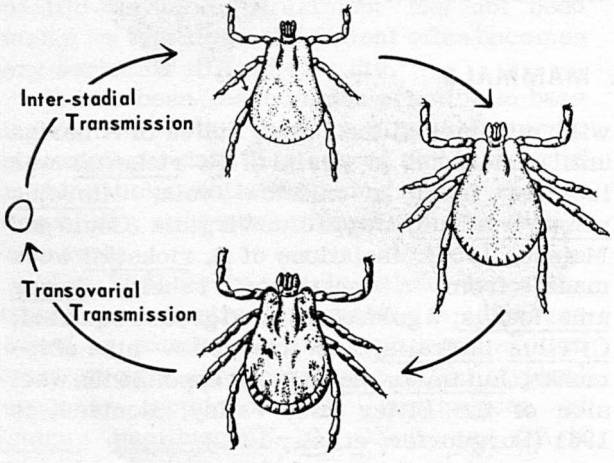
Table 5.—*Mammals whose sera have been found to contain C-F antibodies for spotted fever*

| | | | |
|---|---|---|---|
| *Lepus americanus* | Snowshoe rabbit | *Peromyscus crinitus* | Canyon mouse |
| *Lepus californicus* | Blacktailed jackrabbit | *Peromyscus leucopus* | White-footed mouse |
| *Sylvilagus floridanus* | Eastern cottontail | *Peromyscus maniculatus* | Deer mouse |
| *Sylvilagus nuttalli* | Nuttall cottontail | *Peromyscus truei* | Pinon mouse |
| *Sylvilagus auduboni* | Desert cottontail | *Pitymys pinetorum* | Pine mouse |
| *Marmota monax* | Woodchuck | *Neotoma lepida* | Desert woodrat |
| *Citellus leucurus* | Antelope ground squirrel | *Sigmodon hispidus* | Cotton rat |
| *Citellus columbianus* | Columbian ground squirrel | *Blarina brevicauda* | Short-tailed shrew |
| *Eutamias minumus* | Least chipmunk | *Canis familiaris* | Domestic dog |
| *Eutamias dorsalis* | Cliff chipmunk | *Vulpes fulva* | Red fox |
| *Eutamias amoenus* | Yellow-pine chipmunk | *Urocyon cinereoargentus* | Gray fox |
| *Perognathus longimembris* | Little pocket mouse | *Procyon lotor* | Raccoon |
| *Perognathus parvus* | Great Basin pocket mouse | *Mephitis mephitis* | Striped skunk |
| *Perognathus formosus* | Long-tailed pocket mouse | *Didelphis virginiana* | Opossum |
| *Dipodomys ordi* | Ord kangaroo rat | *Odocoileus virginianus* | White-tailed deer |
| *Microtus pennsylvanicus* | Meadow vole | | |

## EPIDEMIOLOGY: TICKS

Rickettsiae ingested by a tick invade the cells of the epithelial lining of the midgut, and penetrate the intestinal wall to be carried by the open circulatory system to all organs of the body. The blood of a tick (hemolymph) is contained within a single cavity and contacts all tissues. Therefore, all organs, including the reproductive system and salivary glands, can be invaded by the rickettsiae. Invasion of the reproductive system results in transmission from tick to egg (transovarial) and to succeeding stages (interstadial). Invasion of the salivary glands facilitates transmission to mammalian hosts. A tick can inject rickettsiae into a vertebrate host when the salivary gland has been invaded by rickettsiae.

Figure 2.
TICK TRANSMISSION OF PATHOGENS




### Tick Transmission of Rickettsiae

The mouthparts of ticks are short and cannot readily penetrate a capillary. When the mouthparts have been inserted into a host, the tick secretes enzymes and anticoagulants. The enzymes digest tissue cells and capillary walls. Thus, tissue cells as well as blood cells are ingested by the tick. Some ticks may fill to a third of their capacity on tissue fluids before obtaining blood. Since a certain

period is required for the enzymes to digest capillary walls, a tick cannot immediately transmit rickettsiae.

The rickettsiae which survive the winter in a tick are present in a nonsymptom-producing form, and do not produce symptomatically recognizable infections until the level of virulence is raised, either by heat or by the ingestion of blood. This is known as "reactivation." It may be a matter of some hours, or even days, after a tick attaches itself before reactivation occurs. Thus, if a tick which has become attached is removed within a few hours, the danger of infection is materially reduced.

The presence of rickettsiae in the intestinal tract and hemolymph of ticks can be important in the transmission of spotted fever. If an infective tick is crushed between the fingers when handpicking ticks from dogs, the rickettsiae can produce an infection through the unabraded skin. Feces of infective ticks are very infectious, and many infections have probably resulted from the contamination of the skin with tick feces.

If a tick is attached to the body, REMOVE IT IMMEDIATELY. Many practices have been employed for tick removal. The desired result, however, is most easily and quickly accomplished by gently pulling the tick off with the fingers. There is little danger that the mouthparts will be left in the skin, so far as most of the tick vectors of spotted fever are concerned. There is a definite danger of breaking off the mouthparts of ticks which have long hypostomes, such as Ixodes pacificus on the west coast and Amblyomma americanum on southeast coast, Gulf Coast, and south central States. After removing the tick, it is best to examine it to see if the three separate shafts of the mouthparts are still on the tick. If a small particle of skin or flesh is found still attached to the mouthparts between the palpi, it is evidence that no parts have been broken off in the flesh. If it is found that a part has been left in the wound, a minute piece of flesh, sufficient to include the part, should be removed either with fine scissors or a very sharp knife, first sterilizing the instrument. If parts are left in the flesh, the wound will be very slow in healing and may even lead to rather serious complications. When forceps and sterile instruments are available, ticks of any species can be removed easily by pulling the tick gently so as to make a tent of the skin surrounding the site of attachment and then slipping the point of a sterile needle or knife blade under the mouthparts. The instrument is then raised, thus removing the mouthparts with a minimum of tissue. The site of the bite should be treated with iodine or some other antiseptic to prevent a secondary infection. A silver nitrate pencil, which can be obtained at most drugstores, is convenient for outdoor use. The tick should be kept alive in a clean bottle or tin box so that it may be shown to the physician if necessary.

Figure 3.
*DERMACENTOR* MOUTHPARTS

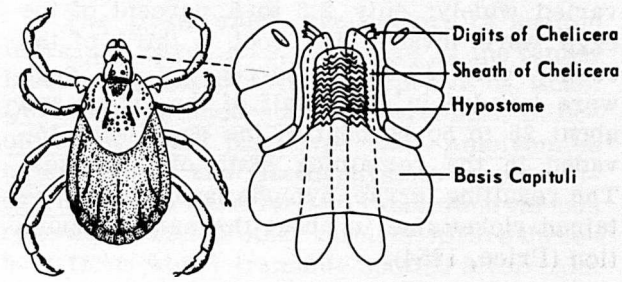
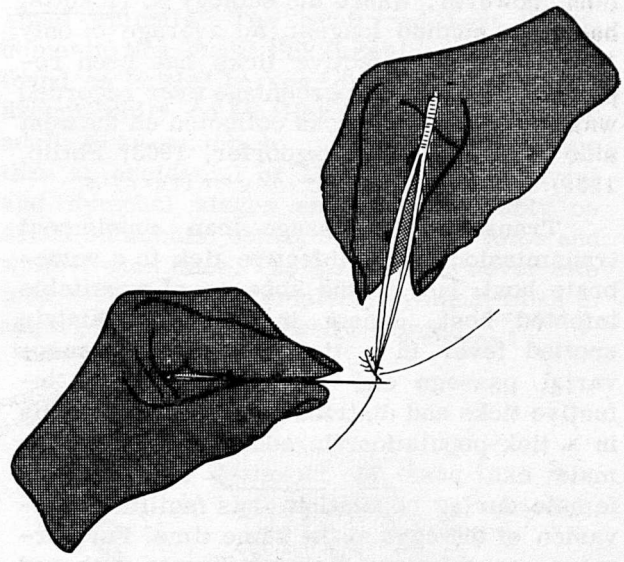



Figure 4.
CORRECT TICK REMOVAL

1. Grasp tick near mouthparts and lift gently upward and forward.
2. Insert needle between skin and tick and pry out tick.
3. Disinfect site of bite immediately.



Do Not Squeeze Body of Tick With Forceps

Do Not Break Tick

Do Not Rub Site of Bite Prior to Complete Disinfection

## Ticks as Reservoirs of Spotted Fever

The transovarial transmission of spotted fever is important in maintaining the rickettsiae within a tick population. The exact importance of such passage varies between species of ticks. In recent tests, all experimentally and naturally invaded female D. andersoni transmitted R. rickettsi to almost 100 percent of their progeny. The rickettsiae were retained throughout the developmental stages of the first two succeeding generations (Burgdorfer, 1963). Transovarial passage of R. rickettsi occurred in only 30 to 40 percent of infective female D. variabilis, and the number of invaded eggs from each female varied widely: only 2.5 to 5 percent of the eggs were invaded in about a third of the cases; only 10 to 20 percent of the eggs were invaded in about half of the cases; and about 25 to 50 percent of the eggs were invaded in the remaining sixth of the cases. The resulting larvae, nymphs, and adults contained rickettsiae in about the same proportion (Price, 1954).

It would appear that transovarial passage of R. rickettsi to offspring of D. andersoni and the simultaneous feeding of infective and normal ticks on host animals represent efficient mechanisms by which this agent is disseminated naturally. It would seem logical, therefore, to find a relatively high percentage of infective ticks in areas where spotted fever is endemic. In the Bitter Root Valley of Montana, however, where the ecology R. rickettsi has been studied longest, an average of only 1 to 3 percent infective ticks has been reported. The highest percentage ever recorded was 13.5 percent in ticks collected on the west side of the valley (Burgdorfer, 1963; Philip, 1959).

Transovarial passage can supplement transmission by an infective tick to a vertebrate host, but, in the absence of a suitable infected host, cannot indefinitely maintain spotted fever in a tick population. Transovarial passage can start new lines of infective ticks and distribute R. rickettsi widely in a tick population. In addition, an infective male can pass R. rickettsi to a normal female during copulation, thus facilitating invasion of the eggs at the same time. Furthermore, an infective male may mate with and allow the rickettsiae to invade more than one female, thus starting several new lines of infective ticks.

Interstadial passage is the ability of the rickettsiae to pass through the egg to the larval stage, or, if acquired during the larval or nymphal stage, to pass on to subsequent stages. Interstadial passage maintains, as well as distributes, spotted fever in a tick population. It is very important in distributing spotted fever to vertebrate hosts. Spotted fever is rarely transmitted by the development stage which acquired the organism. Hard ticks usually feed to repletion in one uninterrupted feeding, then do not feed again while in that stage. Thus, a tick could not normally transmit R. rickettsi without interstadial passage.

The ability of ticks to survive adverse weather conditions contributes to the maintenance of spotted fever within a tick population. In general, the larval and nymphal stages of a three-host tick usually have to feed within a year and rarely survive the winter without a blood meal. The adult, however, can usually survive for two or three years without feeding. This ability of the tick to survive thus enables R. rickettsi to survive the winter, and also maintain the rickettsiae for long periods of time in the absence of a suitable vertebrate host.

Adults of D. variabilis have been found to live three years without a blood meal. In an experiment, D. variabilis larvae were fed on guinea pigs which were infected with a strain of R. rickettsi of low virulence. Several lots of these ticks were kept in longevity tubes which were placed in the ground in October, two weeks after molting to adults. The tubes were removed at the end of April and kept on the ground under shady foliage. This cycle was repeated. At two-month intervals, 12 ticks from each lot were tested in groups of 4 for rickettsiae. All lots began to lose their infectiveness quite rapidly after 8 months. None of the ticks showed any rickettsiae by the end of 16 months. Further tests were conducted to determine if rickettsiae could be demonstrated in these ticks. All lots were negative (Price, 1954).

## Factors Affecting Spotted Fever Infection Rates

A focus of infected ticks is relatively fixed and localized. Widespread epidemics, such as those associated with some mosquito-borne diseases, therefore, have not occurred.

In the western endemic States, the main vector of spotted fever is D. andersoni. Adults of this tick feed primarily on large wild

mammals (mountain goat, deer, elk) as well as range cattle, while the immature stages feed primarily on small wild rodents. This feeding preference tends to keep the ticks away from areas of human habitation, since the host animals are most frequently found in areas away from human habitation. In the eastern endemic States, the main vector is D. variabilis, a much more domesticated tick. Adults of this tick feed on dogs, cows, and horses, while the immature stages feed on small rodents such as meadow voles, and rabbits. This feeding preference tends to bring the ticks into areas around human habitation, since the host animals are frequently found in areas around human habitations. This difference in tick ecology seems to partly account for the higher human incidence reported for the eastern endemic States than for the western endemic States.

Annual incidence of spotted fever depends partly on the abundance of infected ticks, partly on meteorological conditions, and partly on unknown factors.

No marked correlation has been observed between the abundance of ticks and the prevalence of cases. It is probable that prevalence of infection, other factors being equal, is more closely related to the percentage of ticks containing symptom-provoking rickettsiae than to tick abundance.

It is probable that spotted fever seldom dies out in a locality unless agriculture becomes so intensified that the wild animal hosts necessary to maintain a tick population are essentially exterminated. As agriculture develops, there is likely to be a drop in prevalence in some areas and an increase in others (Parker, 1933).

As agriculture declines in an area and as farms or even portions of farms are retired from cultivation, grasses, weeds, and shrub growth very soon occupy fields that have been tilled for years. The vegetative cover provides an environment well adapted to support large populations of the meadow vole (one of the principal hosts of the immature ticks) as well as other less-favored hosts. The same tracts afford better protection for foxes and other wild animals which serve as hosts for adults than did the original, cleared fields. This increase in favorable environmental areas naturally supports a greater population of rodents, and, consequently, of ticks that are dependent upon such hosts for survival (MacCreary, 1945).

Meteorological conditions affect the abundance of ticks. Very dry years are unfavorable for ticks, resulting in a reduction in the tick population, and thus in fewer infected ticks. Ticks are also not as active in dry years, so the probability of an infected tick finding a human host is also reduced. Conversely, very wet years are very favorable for ticks, resulting in an increase in the tick population, and thus an increase in infected ticks. Ticks are also more active in very wet years, so the probability of an infected tick finding a human host is also increased.

### Tick Vectors of Spotted Fever

The ticks which are vectors of spotted fever are hard ticks, members of the family Ixodidae. Spotted fever is spread by ticks: Dermacentor andersoni, D. variabilis, D. occidentalis, D. parumapertus, Amblyomma americanum, and Haemaphysalis leporispalustris. These ticks feed on rabbits and various rodents as well as other animals. All are three-host ticks which transmit spotted fever from mammal-to-mammal, and also from tick-to-tick via transovarial and interstadial passage.

The American dog tick, D. variabilis, is the principal vector of spotted fever east of the Rocky Mountains. This tick is widely distributed east of the Rocky Mountains and is also found on the Pacific Coast, as shown by the accompanying map. Its life cycle requires from 4 to 12 months. Most adult ticks attach to and engorge on medium- to large-sized animals. The preferred host is the domestic dog. Adult ticks are also occasionally found on cattle, horses, cats, and foxes, and, exceptionally, on smaller mammals. While the adult ticks attach to man, man is no more than an accidental or stray host. The larval and nymphal stages engorge preferably on small mammals, especially meadow voles and white-footed mice. The larval ticks never bite man, while a few attempts by nymphal ticks to engorge on man have been recorded.

Figure 5.

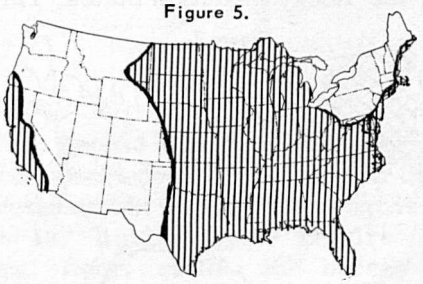
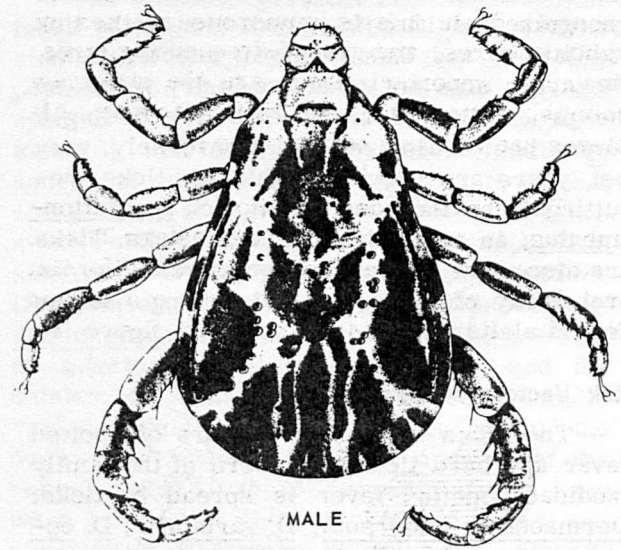
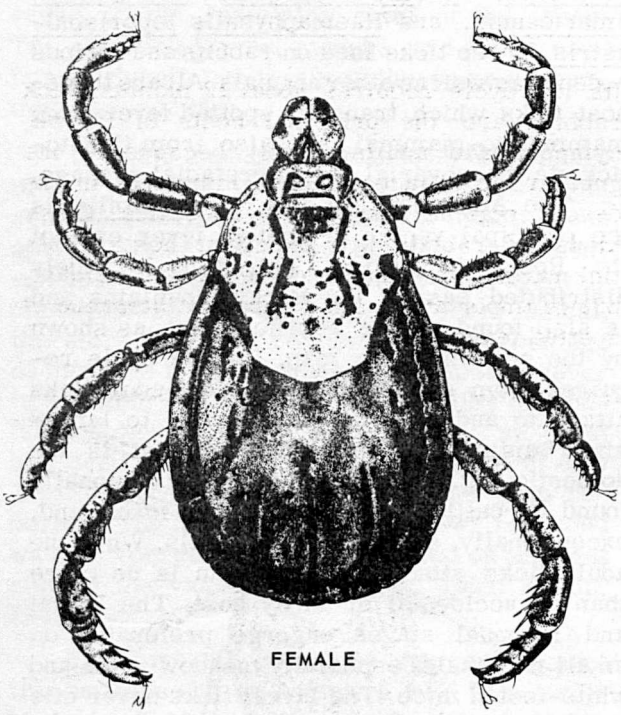


Figure 6.
AMERICAN DOG TICK *(DERMACENTOR VARIABILIS)*



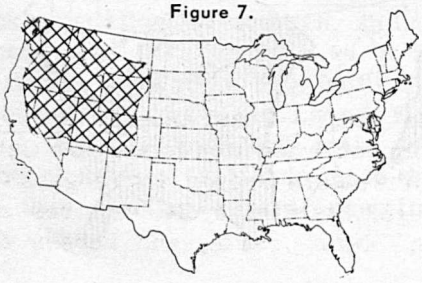
MALE



FEMALE

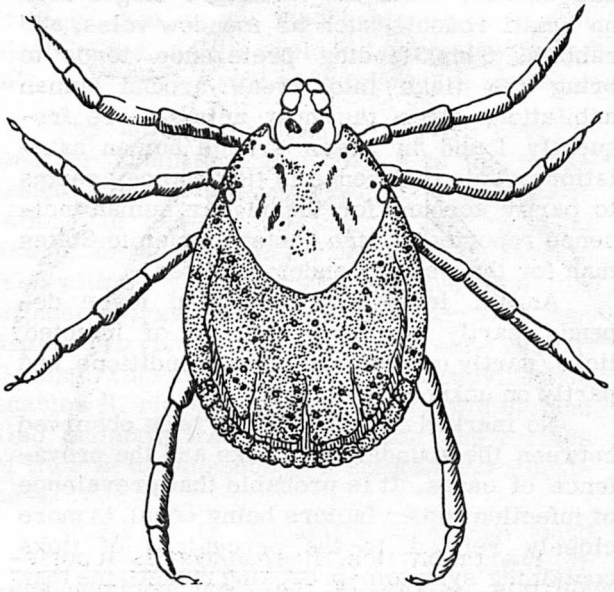
The Rocky Mountain wood tick, D. andersoni, is the principal vector of spotted fever in the Rocky Mountain States. This tick

Figure 7.



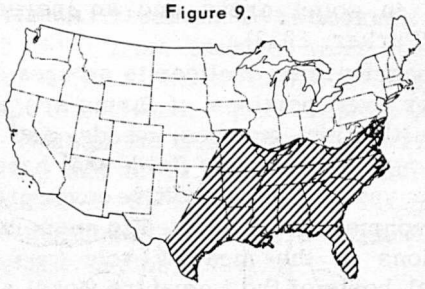
is found in the Rocky Mountain region, as shown by figure 7. Its life cycle requires 2 to 3 years. Adult ticks attach to and engorge on horses, cattle, sheep, mountain goats, deer, elk, bears, and coyotes. The larval and nymphal ticks feed mainly on ground squirrels, chipmunks, pine squirrels, and mice. Only the adult tick bites man.

Figure 8.
*DERMACENTOR ANDERSONI* ROCKY MOUNTAIN WOOD TICK



The lone star tick, Amblyomma americanum, is the principal vector of spotted fever in the south central and Gulf Coast States.

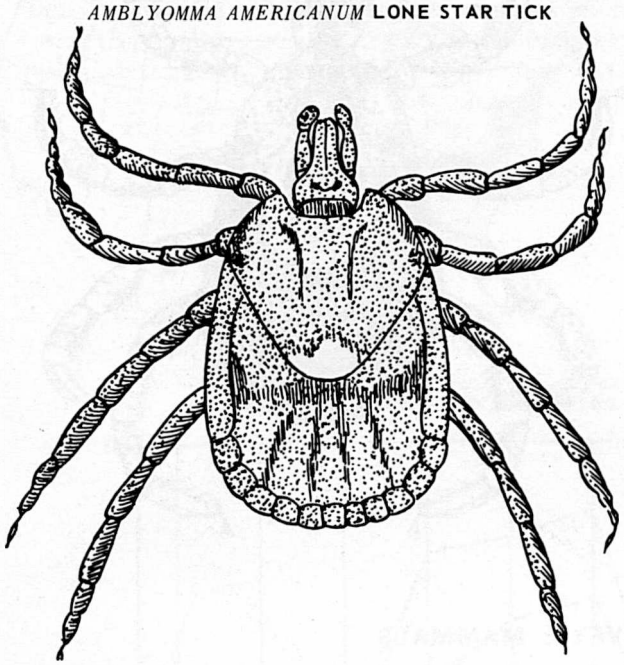
Figure 9.



This tick is abundant in the Gulf Coast States, and is plentiful along the South Atlantic Coast and in parts of Oklahoma, Arkansas, and Missouri, as shown by figure 9. Its life cycle requires about 2 years. This tick shows little host preference. All stages bite man and other large mammals, notably deer, cattle, horses, and dogs. Adult ticks do not commonly occur on the smaller mammals, but both larval and

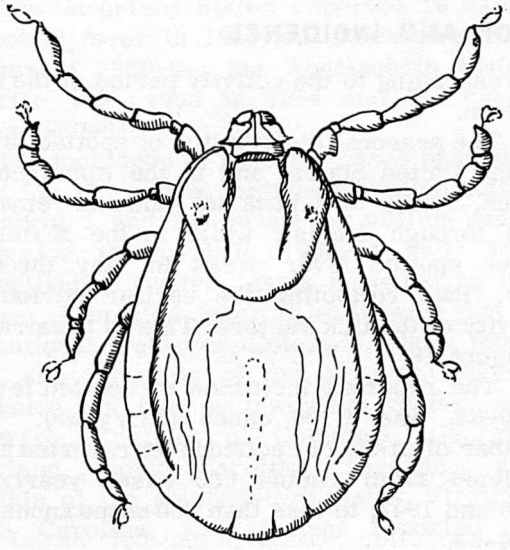
nymphal stages feed on rabbits, squirrels, foxes, raccoons, and skunks, as well as quail and wild turkeys.

Figure 10.
*AMBLYOMMA AMERICANUM* LONE STAR TICK



The rabbit tick, Haemaphysalis leporis-palustris, is one of the most common and widely distributed ticks in North America. It is found in all of the United States of America except possibly Hawaii. Its life cycle requires about 75 days. Although the rabbit tick rarely bites man, it is very important in the natural maintenance of spotted fever. The rabbit tick

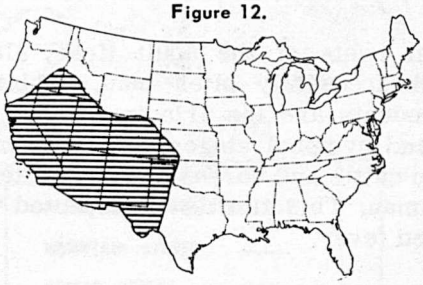
Figure 11.
*HAEMAPHYSALIS LEPORISPALUSTRIS* RABBIT TICK



is the only tick which occurs in all parts of North America where spotted fever has been recognized. It infests numerous species of rabbits, hares, and ground-frequenting birds. Its most important hosts are the snowshoe rabbits, cottontails, and ruffed grouse. All stages can be found on the same host.

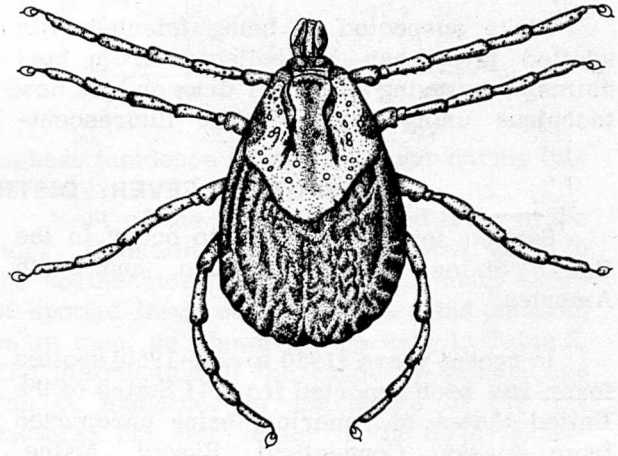
The "rabbit dermacentor," D. parum-apertus, is most abundant in western Texas, southern New Mexico, Arizona, and California, and fairly abundant in some parts of Utah and Nevada. Its range is shown in figure 12.

Figure 12.



Its life cycle requires about 12 months. Jack rabbits are the principal hosts of larvae, nymphs, and adults, partly because of the greater abundance of these mammals in the desert regions inhabited by this tick. Other kinds of rabbits are excellent hosts. This tick rarely bites man or domesticated animals, but is important in the natural maintenance of spotted fever.

Figure 13.
*DERMACENTOR PARUMAPERTUS* RABBIT DERMACENTOR



The Pacific Coast tick, D. occidentalis, is a common wood tick in western California and southwestern Oregon. Its range is shown in figure 15. Its life cycle requires about 3 months. Deer, cattle, and horses are the

Figure 14.

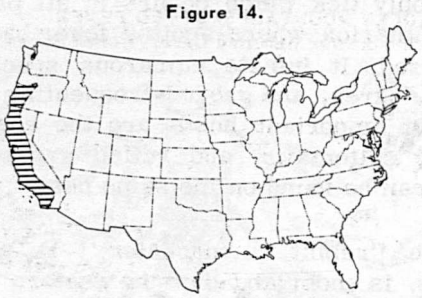
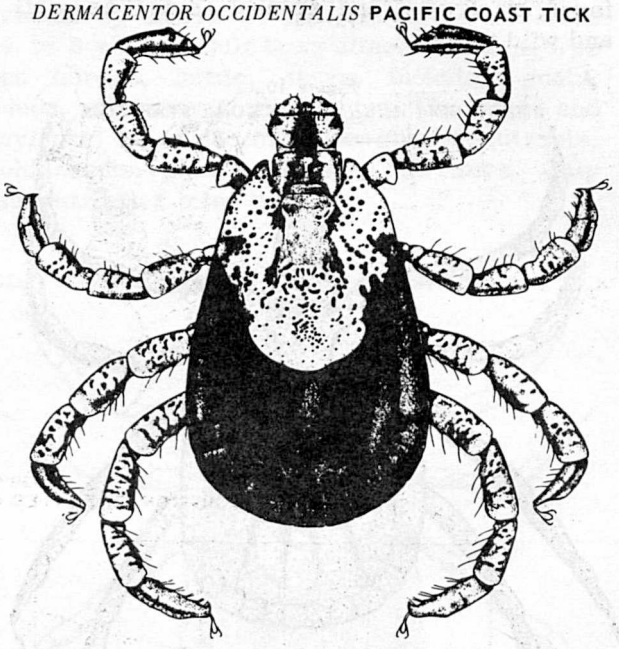


Figure 15.
*DERMACENTOR OCCIDENTALIS* PACIFIC COAST TICK



principal hosts of the adult ticks, although this tick frequently bites man. Rabbits and small rodents are the principal hosts of the larval and nymphal stages. The nymphs will attach to cattle and horses and have attempted to bite man. This tick is a suspected vector of spotted fever.

## SPOTTED FEVER SURVEYS: MAMMALS

Surveys may be made to determine which mammals are serving as reservoirs of spotted fever. Some specimens should be collected for identification. Live-catch traps should be used to take the animals alive. The animals are anesthetized, ectoparasites collected, and a blood sample taken. The sera is separated from the whole blood, frozen, and sent to a laboratory for complement-fixation tests. These surveys are mainly used for research.

## SPOTTED FEVER SURVEYS: TICKS

Ticks suspected of being infected with spotted fever can be collected from host animals, by using a flannel drag or by a new technique using dry ice. The fluorescent-antibody technique is used to determine the presence of R. rickettsi in these ticks. These surveys are mainly used for research.

## SPOTTED FEVER: DISTRIBUTION AND INCIDENCE

Spotted fever is known to occur in the United States, Canada, Mexico, and South America.

In recent years (1960 to mid-1965) spotted fever has been reported from 44 States of the United States of America, being unreported from Alaska, Connecticut, Hawaii, Maine, Vermont, and Wisconsin. Spotted fever has never been reported from Alaska, Hawaii, Maine, and Vermont. This distribution of cases is shown in figures 16 and 17.

Spotted fever has been reported in each month of the year. Most of the spotted fever cases are reported in late spring and summer, corresponding to the activity period of the tick vectors.

The seasonal distribution of spotted fever in the United States, and in the Appalachian States, builds to a peak in June and remains high through August, while in the Mountain States spotted fever peaks in May through July, thus reflecting the earlier period of activity of the tick vectors. This is illustrated in figure 18.

The reported incidence of spotted fever, 1960-64, was 1,106 cases (221/year). The number of cases of spotted fever reported have declined from almost 600 cases yearly in 1946 and 1947, to less than 300 cases annually, 1954-64.

Figure 16.
ROCKY MOUNTAIN SPOTTED FEVER CASES
1951-55

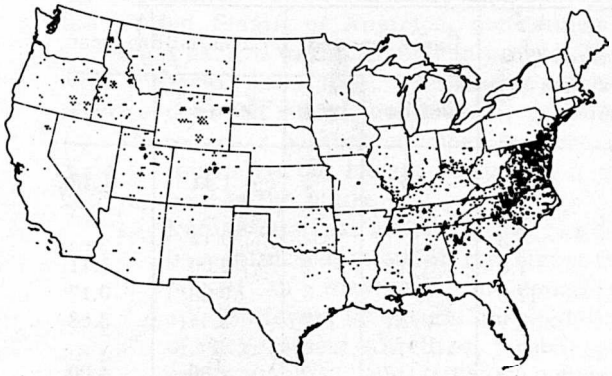


Figure 17.
ROCKY MOUNTAIN SPOTTED FEVER
Counties With 1 or More Reported Cases, United States, 1963

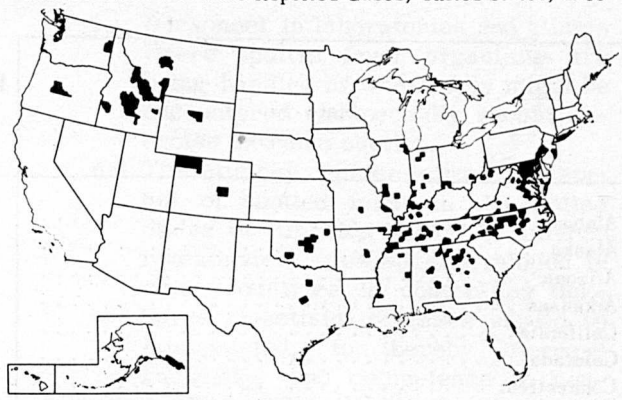
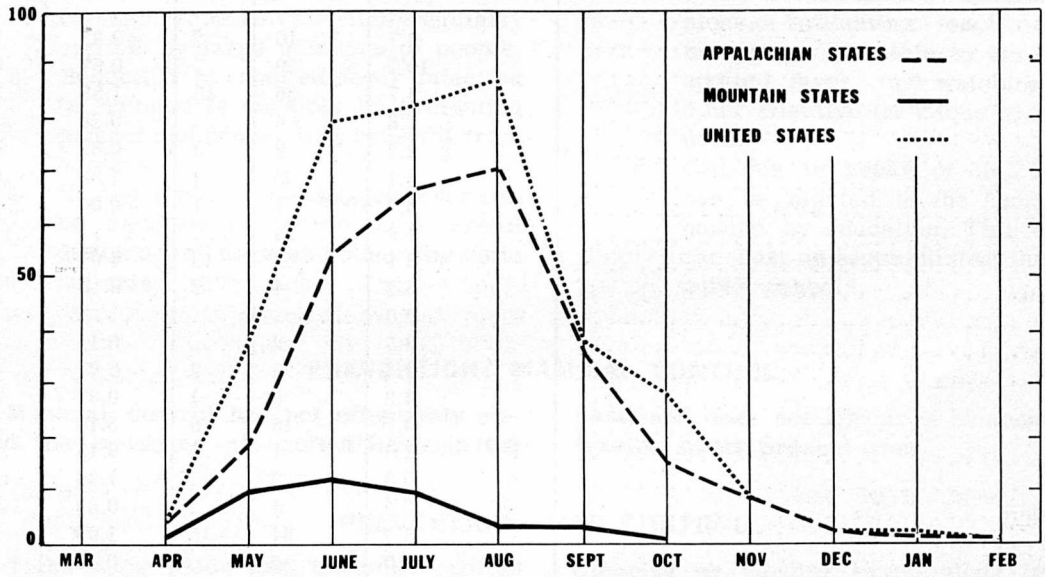


Figure 18.
SEASONAL DISTRIBUTION, REPORTED CASES OF SPOTTED FEVER, 1962-1963




The Mountain States reported 19 cases of spotted fever in 1964 and 82 cases during the period 1960-64; the Appalachian States reported 169 cases in 1964 and 715 cases during 1960-64.

The incidence of reported cases of spotted fever for the entire continental United States was about 1 and 1.5 cases per million population for the periods 1960-64 and 1964, respectively. Twelve States reported an incidence of spotted fever at least twice that of the national incidence: Colorado, Idaho, Montana, and Wyoming of the Mountain States; Oklahoma of the southwestern States; and Delaware, District of Columbia, Georgia, Maryland, North Carolina, Tenessee, and Virginia of the southeastern States. Virginia, North Carolina, and Montana reported the highest incidence of spotted fever during this period.

Most of the cases of spotted fever in the Rocky Mountain States occur in men, while in the southeastern States about as many cases of spotted fever occur in women and children as in men, as shown by the data in Table 2. The distribution of the cases by sex and age can be explained by the habits of the tick vectors. The tick vector in the Rocky Mountain States is D. andersoni, which is found in areas away from human habitation, thus the only persons exposed are those who enter these areas, either through occupation or for recreation. The tick vector in the eastern States is D. variabilis, which is almost a domestic tick, being found frequently around human habitations.

Table 6.—*Distribution and incidence of reported cases of Spotted fever in the United States of America, 1960-64 and 1964*

| State | Estimated 1962 population in millions | Cases reported | | Cases/million/year | |
|---|---|---|---|---|---|
| | | 1960-64 | 1964 | 1960-64 | 1964 |
| Alabama | 3.4 | 24 | 4 | 1.41 | 1.18 |
| Alaska | 0.2 | ..... | ... | ..... | .... |
| Arizona | 1.5 | 1 | ... | 0.12 | .... |
| Arkansas | 1.8 | 18 | 2 | 2.00 | 1.11 |
| California | 17.0 | 7 | 3 | 0.08 | 0.17 |
| Colorado | 1.9 | 27 | 7 | 2.84 | 3.68 |
| Connecticut | 2.6 | ..... | ... | ..... | .... |
| Delaware | 0.5 | 7 | 2 | 2.80 | 4.00 |
| District of Columbia | 0.8 | 10 | 3 | 2.50 | 3.75 |
| Florida | 5.5 | 4 | 1 | 0.14 | 0.18 |
| Georgia | 4.1 | 63 | 17 | 3.07 | 4.15 |
| Hawaii | ..... | ..... | ... | ..... | .... |
| Idaho | 0.7 | 10 | 2 | 2.85 | 2.85 |
| Illinois | 10.1 | 29 | 7 | 0.57 | 0.69 |
| Indiana | 4.7 | 36 | 18 | 1.53 | 3.83 |
| Iowa | 2.8 | 4 | ... | 0.28 | .... |
| Kansas | 2.2 | 9 | 3 | 0.82 | 1.36 |
| Kentucky | 3.1 | 28 | 3 | 1.80 | 0.97 |
| Louisiana | 3.3 | 1 | 1 | 0.06 | 0.30 |
| Maine | 1.0 | ..... | ... | ..... | .... |
| Maryland | 3.1 | 64 | 18 | 4.09 | 5.81 |
| Massachusetts | 5.2 | 4 | 2 | 0.16 | 0.38 |
| Michigan | 8.0 | ..... | ... | ..... | .... |
| Minnesota | 3.5 | 2 | ... | 0.11 | .... |
| Mississippi | 2.2 | 3 | 2 | 0.27 | 0.91 |
| Missouri | 4.3 | 8 | 1 | 0.37 | 0.23 |
| Montana | 0.7 | 18 | 6 | 5.14 | 8.57 |
| Nebraska | 1.5 | 1 | ... | 0.13 | .... |
| Nevada | 0.3 | 2 | ... | 1.33 | .... |
| New Hampshire | 0.6 | 1 | ... | 0.33 | .... |
| New Jersey | 6.2 | 31 | 16 | 1.00 | 2.58 |
| New Mexico | 1.0 | 2 | ... | 0.40 | .... |
| New York | 17.4 | 28 | 2 | 0.32 | 0.11 |
| North Carolina | 4.7 | 162 | 43 | 6.89 | 9.15 |
| North Dakota | 0.6 | 2 | 1 | 0.67 | 1.67 |
| Ohio | 10.1 | 38 | 12 | 0.75 | 1.19 |
| Oklahoma | 2.4 | 43 | 8 | 3.58 | 4.06 |
| Oregon | 1.9 | 9 | 2 | 0.95 | 1.05 |
| Pennsylvania | 11.4 | 38 | 15 | 0.67 | 1.32 |
| Rhode Island | 0.9 | 1 | ... | 0.22 | .... |
| South Carolina | 2.4 | 15 | 2 | 1.25 | 0.83 |
| South Dakota | 0.7 | 3 | 1 | 0.86 | 1.43 |
| Tennessee | 3.6 | 98 | 28 | 5.44 | 7.78 |
| Texas | 10.1 | 8 | 2 | 0.16 | 0.20 |
| Utah | 1.0 | 5 | 1 | 1.00 | 1.00 |
| Vermont | 0.4 | ..... | ... | ..... | .... |
| Virginia | 4.2 | 206 | 35 | 9.81 | 8.33 |
| Washington | 3.0 | 2 | ... | 0.13 | .... |
| West Virginia | 1.8 | 17 | 4 | 0.89 | 2.22 |
| Wisconsin | 4.1 | ..... | ... | ..... | .... |
| Wyoming | 0.4 | 17 | 3 | 8.50 | 7.50 |
| United States total | 185.6 | 1,106 | 277 | 1.19 | 1.49 |

## PREVENTION: GENERAL

Spotted fever, ecologically entrenched in the United States of America, constitutes a perpetual hazard to the American people. Yet, with present knowledge, eradication of the disease does not seem economically feasible.

There are a number of things that can be done to minimize the hazard of spotted fever both now and in the future:

1. Human contacts with infected ticks can be minimized, particularly during the period of maximum incidence of spotted fever, by thoughtful scheduling of recreational activities, jamborees, encampments, and outdoor conventions.
2. Human contacts with infected vectors can be limited by environmental and chemical control at sites regularly visited by large numbers of people.
3. Reduction in spotted fever infection in humans is possible by promoting prompt and proper tick removal from humans.
4. Human incidence of spotted fever can be reduced by proper and careful deticking of dogs and other domestic animals.
5. Personnel in laboratories and clinics where spotted fever organisms are being handled or where they might be encountered unexpectedly should exercise extreme caution.
6. The etiology, epidemiology, and status of spotted fever in the United States of America should be further investigated, knowledge developed in other countries in controlling tick-borne rickettsial diseases should be interpolated, to thereby increase knowledge and competence in controlling spotted fever.
7. A coordinated disease control program can be initiated, using any and every economically feasible technique, evaluating each technique insofar as possible by its effect on spotted fever, and watching for any other effective technique which can be used.
8. Citizens in areas of high incidence can be alerted to the spotted fever hazard by education. This education can best be accomplished through the public schools.

## PREVENTION: MAMMAL CONTROL

Mammal control has not effectively reduced the incidence of spotted fever in the past, and does not appear to be economically feasible at the present time.

## PREVENTION: TICK CONTROL

Ticks suck blood and transmit spotted fever, tularemia, relapsing fever, and other diseases to man. Toxic tick saliva may cause paralysis in man. Hard ticks harbor on and under vegetation; soft ticks, in or near the host's nest. Either may infest homes. Remove attached ticks with care. Disinfect the bite. In disease areas, or if bite reaction is severe, consult a physician.

An individual may obtain some degree of protection against ticks by keeping the clothing buttoned, by tucking the trouser legs into the tops of the socks or boots, and by tucking the shirttail into the trousers. The individual should avoid sitting on the gound or on logs in brushy areas. Inspecting the clothing and body and removing ticks before they attach will protect against exposure to spotted fever, tick paralysis, and other tick-borne diseases. Clearing or burning brush along paths and keeping weeds and grass cut in recreational areas reduces the likelihood of tick infestation. In residential areas closely-cut lawns and well-kept yards help control both ticks and their small rodent hosts.

If ticks become attached, the simplest method of removing them is by a slow steady pull (using tweezers or forceps, not bare hands) that will not break off the mouthparts and leave them in the wound. There is no certain way to make a tick detach its mouthparts. Certain materials have been found, through experience or experimentally, to cause a tick to loosen its mouthparts. All of these materials, however, do require a period of time, so it is best to simply remove the tick with tweezers or forceps. An antiseptic should always be applied to tick bites just as to

other open wounds. If the hands have touched the tick during removal, wash them thoroughly with soap and water since the tick secretions may be infective.

Many repellents have been tested against ticks, but no known chemical is effective against all species. The application of a repellent to exposed skin provides little protection against ticks since they crawl underneath clothing and attach on untreated portions of the body. The application of repellents to the entire body might prevent attachment for a few hours, but such extensive treatments are impractical and might be injurious. For these reasons, clothing treatments with repellents are suggested instead of skin treatments. Indalone, diethyl toluamide, dimethyl carbate, dimethyl phthalate, and benzyl benzoate provide up to 90 percent protection. The repellency of M-1960, the present military clothing treatment, to ticks is due primarily to the presence of butylacetanilide, although the benzyl benzoate and butyl ethyl propanediol are also moderately good tick repellents. Clothing should be saturated with a solution or emulsion of the repellent by dipping the garment into it or by pouring on enough to saturate the garment. A five percent solution or emulsion will produce a deposit of about 2 grams a square foot on denim, ordinary cotton khaki or light wool clothing. About three pints are required to wet thoroughly a complete outfit of shirt and trousers of these fabrics. After the clothing has been wetted, it should be wrung out by hand, hung outdoors, and allowed to dry thoroughly before it is worn. Properly treated clothing will provide good to excellent protection against ticks, as well as chiggers and mosquitoes, for several days to a week if it is not subjected to wetting by rains or by wading in streams or lakes. Clothing should be thoroughly washed and re-treated at weekly intervals or before infrequent outdoor excursions.

Many of the ticks in an infested area can be controlled by applying an insecticidal spray or dust to the ground or vegetation. The most satisfactory material for this purpose is DDT, as it provides a high initial kill and a lasting residual action. It may be applied as a spray or as a dust, whichever is more convenient. By either method, from two to three pounds of DDT per acre should be applied.

It is usually necessary to spray only along paths and roadsides where ticks are found, or are likely to occur. Where ticks appear on dogs or man frequently, all the paths, roadsides and edges of open lawns and fields should be dragged. If the area is large, the spraying may then be confined to the spots shown by observation and dragging to be heavily infested. If the area is small, all the suspected paths, roadsides, and edges of open places may be sprayed without undue expense.

To spray large areas indiscriminately is wasteful and unnecessary. Furthermore, where wide, continuous areas are treated, solutions that are too weak for effective tick control sometimes have to be used to avoid danger or injury to wildlife.

The equivalent of one-third of an ounce of pure DDT spread over a strip of roadside vegetation 100 feet long and 2 feet wide is a dosage which has produced good tick control for several weeks. This is conveniently applied in small areas with a 1- to 3-gallon compressed air sprayer at a rate of about 3 miles per hour (100 feet in about 23 seconds). Where long stretches of roadside are to be treated, power equipment may be used to advantage. Twenty-four gallons of a 2.5 percent emulsion will treat a strip 4 feet wide and 2 miles long.

Even heavier dosages could be used without danger to wildlife when applied to narrow roadside strips. If the first treatment is applied early and if the tick population builds up again because of reinfestation, a second treatment may be necessary after several weeks.

Dogs and cats may be freed of ticks, using a liquid or dust containing about 0.75 to 1 percent rotenone, or dusts containing 3 to 5 percent malathion. Dogs, but not cats, may also be treated with dusts containing 1 percent lindane, 2 to 3 percent chlordane, or 5 percent DDT.

A new development in the control of ticks on dogs is the use of one of the less toxic organic phosphate insecticides, ronnel, as a systemic insecticide. In pill form this is sold only by or on order of a licensed veterinarian. For a 10-pound dog, one 500 milligram tablet is administered every two days for four treatments, then 1 tablet weekly thereafter to prevent reinfestation.

Tick control is economically feasible and bionomically practical only on limited areas or along human pathways.

## SELECTED REFERENCES


Anonymous. 1960. Studies on the ecology and epizoology of the native fauna of the Great Salt Lake Desert. Ecology and Epizoology Series No. 44. Univ. Utah, Salt Lake City. 67 pp.

Bell, E. J., and Pickens, E. G. 1953. A toxic substance associated with the rickettsiae of the spotted fever group. J. Immunol., 70:461-472.

Bishopp, F. C., Smith, C. N., and Gouck, H. K. 1946. Combating the American dog tick, carrier of Rocky Mountain spotted fever in the central and eastern States. U.S. Dept. Agr., Agr. Res. Serv., Bureau Ent. Plant Quar. Bull. E-454, 5 pp.

Bishopp, F. C., and Trembly, H. L. 1945. Distribution and hosts of certain North American ticks. J. Parasitol., 31:1-54.

Burgdorfer, W. 1963. Investigation of "trans-ovarial transmission" of Rickettsia rickettsii in the wood tick, Dermacentor andersoni. Exper. Parasitol., 14:152-159.

Burgdorfer, W., and Lackman, D. B. 1960. Identification of Rickettsia rickettsii in the wood tick, Dermacentor andersoni, by means of the fluorescent antibody. J. Infect. Dis., 107:241-244.

Burgdorfer, W., Newhouse, V. F., Pickens, E. G., and Lackman, D. B. 1962. Ecology of Rocky Mountain spotted fever in western Montana. I. Isolation of Rickettsia rickettsii from wild mammals. Amer. J. Hyg., 76:293-301.

Collins, D. L., and Nardy, R. V. 1950. Effect of DDT spray residues on larvae of the tick Dermacentor variabilis, Say. J. Econ. Ent., 43:861-863.

Cooley, R. A. 1932. The Rocky Mountain wood tick. Montana State College, Agr. Exp. Sta. Bull. No. 268, Bozeman, 57 pp.

Cox, H. R. 1959. The Spotted Fever group. IN: Viral and rickettsial diseases of man. Rivers and Horsfall, Ed. J. P. Lippincott, Philadelphia, Pa.

Davis, A. T. 1947. Public health aspects of Rocky Mountain spotted fever. New York State J. Med., 47:1596-1600.

Dorer, R. E., Elisberg, B. L., Shirai, A., Sonenshine, D. E., Atwood, E. L., Lamb, J. T., Woroneck, P. P., Mullman, T. M., Banks, J., Rudolph, C. L., and Anastos, G. 1965. Ecology of Rocky Mountain spotted fever. Final Report (1960-64). Virginia State Dept. Health, 167 pp.

Giminez, D. F. 1964. Staining rickettsiae in yolk-sac cultures. Stain Technology, 39: 135-140.

Glasgow, R. D. and Collins, D. L., 1946. Control of the American dog tick, a vector of Rocky Mountain spotted fever. J. Econ. Ent., 39:235-240.

Glasgow, R. D., and Collins, D. L. 1948. Ecological, economic, and mechanical considerations relating to the control of ticks and Rocky Mountain spotted fever on Long Island. J. Econ. Ent., 41:427-431.

Gouck, H. K., and Smith, C. N. 1947. DDT to control wood ticks. J. Econ. Ent., 40: 303-308.

Harrel, G. T. 1949. Rocky Mountain spotted fever. Medicine, 28:333-370.

Hersey, D. F., Colvin, M. C., and Shepard, C. C. 1957. Studies of the serologic diagnosis of murine typhus and Rocky Mountain spotted fever. J. Immum. 79: 409-415.

Knight, K. L., Bryan, D. E., and Taylor, C. W. 1962. Studies on the removal of embedded lone star ticks, Amblyomma americanum. J. Econ. Ent., 55:273-276.

Knutson, H. 1952. A community project for the control of the American dog tick. J. Econ. Ent., 45:889-990.

Kohls, G. M., and Brennan, J. M. 1947. The lone star tick Amblyomma americanum. Federal Security Agency, USPHS, Rocky Mountain Lab., Hamilton, Montana, Circ. No. 14, 5 pp.

Lackman, D. B., and Gerloff, R. K. 1953. The effect of antibiotic therapy upon diagnostic, serologic tests for Rocky Mountain spotted fever. The Public Health Lab., 11:97-100.

MacCreary, D. 1945. Ticks of Delaware with special reference to Dermacentor variabilis (Say) vector of Rocky Mountain spotted fever. Univ. of Delaware, Agr. Exp. Sta., Bull. No. 252, 22 pp.

McDowell, J. W. 1964. Epidemiological consideration in tick-borne disease. Communicable Disease Center, USPHS, 14 pp.

McDuffie, W. C., Eddy, G. W., Clark, J. C., and Husman, C. N. 1950. Field studied with insecticides to control the lone star tick in Texas. J. Econ. Ent., 43:520-527.

Miller, J. K. 1947. Insect vectors of Rocky Mountain spotted fever on Long Island. New York State J. Med., 47:1592-1594.

Parker, R. R. 1938. Rocky Mountain spotted fever. J. Amer. Med. Assoc., 110:1158-1188; 1273-1278.

Parker, R. R. 1941. Rocky Mountain spotted fever: results of fifteen years' prophylactic vaccination. Amer J. Trop. Med., 21:369-383.

Philip, C. B. 1959. Some epidemiological considerations in Rocky Mountain spotted fever. Public Health Rep., 74:595-600.

Pratt, H.D., and Littig, K.S. 1962. Ticks of public health importance and their control. Public Health Serv. Publ., 772(10):42 pp.

Price, W. H. 1953. A quantitative analysis of the factors involved in virulence of rickettsiae. Science, 118:49-52.

Price, W. H. 1954. The epidemiology of Rocky Mountain spotted fever. II. Studies on the biological survival mechanism of Rickettsia rickettsii. Amer. J. Hyg., 60:292-319.

Rivers, T. M., and Horsfall, F. L., Jr. 1959. Viral and rickettsial infections of man. J. P. Lippincott Co., Philadelphia, Pa., xviii + 967 pp., 134 figs.

Shepard, C. C. 1947. Vaccine prophalaxis of Rocky Mountain spotted fever. New York State J. Med., 47:1589.

Shirai, A., Bozeman, F. M., Perri, S., Humphries, J. W., and Fuller, H. S. 1961. Ecology of Rocky Mountain spotted fever. I. Rickettsia rickettsii recovered from a cottontail rabbit from Virginia. Proc. Soc. Exper. Biol. Med., 107:211-214.

Smadel, J. E. 1955. Antibiotic therapy of viral and rickettsial diseases. Bull, New York Acad. Med., 31:704-715.

Smadel, J. E. 1956. Rickettsial Diseases. In Diagnostic Procedures for Virus and Rickettsial Diseases. 2d Ed. Amer. Public Health Assoc., pp. 513-552.

Smadel, J. E. 1959. Status of Rickettsioses in the United States. Ann. Int. Med., 51: 421-435.

Smith, C. N., and Gouck, H. K. 1945. DDT to control ticks on vegetation. J. Econ. Ent., 38:553-555.

Topping, N. H. 1941. Rocky Mountain spotted fever. A note on some aspects of its epidemiology. Public Health Rep., 56: 1699-1703.

Topping, N. H. 1947. The epidemiology of Rocky Mountain spotted fever. New York State J. Med., 47:1585-1587.