TULAREMIA

John W. McDowell
Harold George Scott
Chester J. Stojanovich
Harry B. Weinburgh

U.S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
PUBLIC HEALTH SERVICE
Communicable Disease Center, Training Branch
Atlanta, Georgia
November 1964

CONTENTS

INTRODUCTION

Tularemia is a plague-like disease of rabbits, ticks, man, and other animals caused by the rod-shaped bacterium *Pasteurella* tularensis*. Human cases have been reported, in recent years, in 43 of the United States. It also occurs in Canada, Mexico, Europe, and Asia.

Human cases occur in all months of the year but are more common in late summer and autumn. Arkansas (with 4.6 cases/100,000/year) and Wyoming (with 3.75 cases/100,000/year) have the highest tularemia incidence. Fifty-six percent of all United States cases occur in seven States (Arkansas, Georgia, Illinois, Kansas, Missouri, Virginia, and Wyoming).

The disease is characterized clinically by chills and fever at onset. Prostration is usual. A localized ulcer frequently appears at the site of the original infection. Lymph nodes draining the area of the ulcer become swollen and tender. They commonly suppurate.

Fatality in untreated cases is about 5%. With treatment, fatality is rare. Specific treatment includes streptomycin, the tetracyclines, or chloramphenicol continued until the temperature has been normal four or five days.

Susceptibility is general. Permanent immunity follows recovery except that upon contact with contaminated material an immune person may experience a local tularemic papule.

Laboratory diagnosis is made by inoculation of animals with material from local lesions (or with sputum), bacteriological isolation, agglutination and the fluorescent antibody technique.

The maintenance cycle in nature is from infected to susceptible rabbits via ticks, from which it spills over into other animal populations.

Humans usually contract the disease by handling infected rabbits or through infected tick bites. The incubation period is from 24 hours to ten days, with three days being usual. The disease is not significantly transferable from man to man.

Reduction in incidence of human tularemia is possible with presently available knowledge. It is the purpose of this publication to summarize this knowledge.

* As discussed under HISTORY, a new genus *(Francisella)* has been proposed for this species. It appears that, beginning this year (1964), the name *Francisella* will be used by most workers.

HISTORY

Tularemia was discovered by Dr. George W. McCoy during his investigation of a plague-like epizootic among ground squirrels in Tulare County, California in 1910.

In 1912 with Dr. Charles W. Chapin, Dr. McCoy isolated *Pasteurella tularensis* and demonstrated that it could cause human infections but they did not relate these infections to the human cases clinically described by Martin of Arizona in 1907.

In 1915 Dr. William B. Wherry first recognized that rabbits could transmit tularemia to humans and in 1919, Dr. Edward Francis demonstrated that "deerfly fever" (clinically described by Dr. R. A. Pearse of Utah in 1911) was actually tularemia.

Dr. Francis immediately began investigations which led to elucidation of the deerfly and rabbit transmission cycles as well as certain etiological and immunological aspects of the disease.

The tularemia organism differs sharply from other *Pasteurella* species and a new genus has been proposed to contain it. Because of the great contributions of Dr. Francis to the study of the disease it has been proposed that the organism be called *Francisella tularensis*.

In 1924. Dr. Roscoe S. Spencer and Dr. Ralph R. Parker recognized the tick-borne aspects of tularemia, while, between 1927 and 1936, Dr. Ralph D. Lillie contributed much to the understanding of the pathology of the disease.

Numerous persons have contracted tularemia while studying the organism in the laboratory or being engaged in efforts to control the disease in the field. Dr. Francis contracted a severe infection while investigating "deerfly fever" in Utah in 1919 and suffered four "immune-reaction" episodes between 1920 and 1936. Dr. Spencer and Dr. Parker became seriously ill with the disease during the tick-borne transmission studies in 1924. At least 32 USPHS personnel have contracted the disease during their investigation, and at least two have died: Martin L. Nolan at Hamilton, Montana, in 1931, and Rose Parrott at Baltimore, Maryland, in 1944.

"Scientific research rarely gathers together all the answers to a given problem at one time. A scientist may discover the cause of a disease and still be unable to find a cure. Or, he may have a preventive, as in the case of smallpox vaccination, long before he understands the disease itself. The complete conquest of disease is usu-

ally the result of the combined effort of many workers in different countries laboring over a long period of time, sometimes centuries.

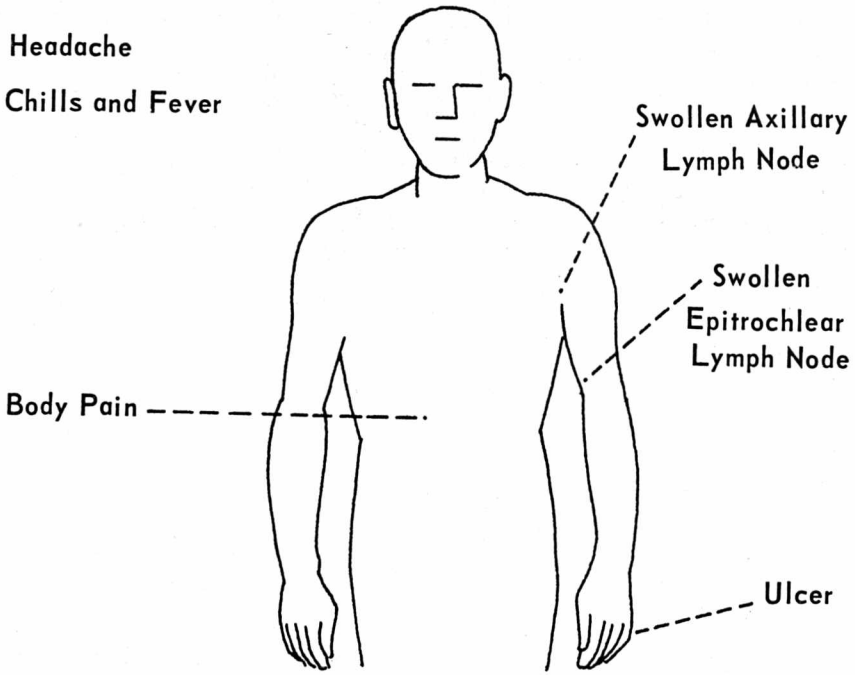
"Tularemia is an outstanding instance in which American investigators have discovered a new infectious disease of man, isolated its causative agent, and determined the sources of infection and methods of transmission to man. . . .

"It illustrates the importance of following through on a 'routine' problem that fails to give the expected immediate results, whether or not there is hope of practical application. Elucidated principally by American investigators, now prevalent in practically all the States, and on three other continents, tularemia has become a world-recognized disease of man and has taken its place in the medical literature of every civilized country" (Williams, 1951).

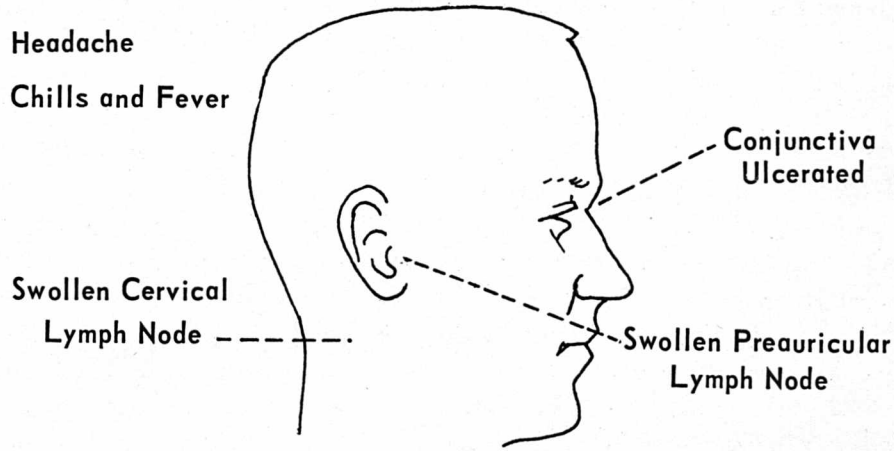
CLINICAL ASPECTS: DESCRIPTION

The classification of clinical types of tularemia in man varies with different workers. However, the following conservative arrangement seems practical:

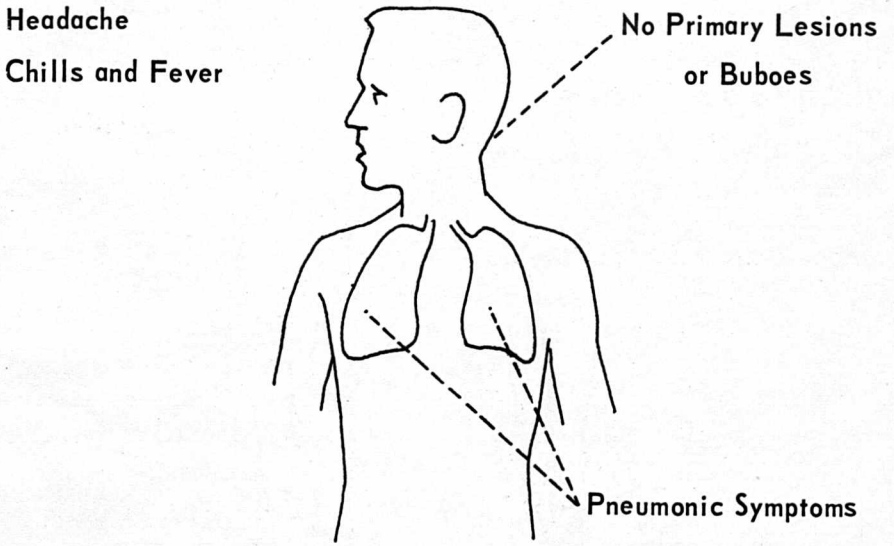
Ulceroglandular Tularemia. This is the most common form of the disease and is usually the easiest to manage. Onset is sudden, with chills and fever. Headache and body pain occur. The patient is usually prostrated. Within three days or even concurrent with these symptoms, a local papule occurs, presumably at the site of infection. This papule develops into an open ulcer about four days after it first appears. The pathogen is retained at the site of the local lesion, probably by the mechanical effects of the inflammation which allows time for mobilization of the immune mechanism. By the time the ulcer develops, extensive infection of the regional lymph nodes has occurred. The axillary and epitrochlear nodes become painful and swollen. In rare cases these nodes break down and discharge purulent material, at which stage the disease is easily mistaken for sporotrichosis. During the first week of the disease bacteremia may occur and, in fulminating cases, septicemic meningitis, or pulmonary involvement may develop. Duration of the disease is two to four weeks.



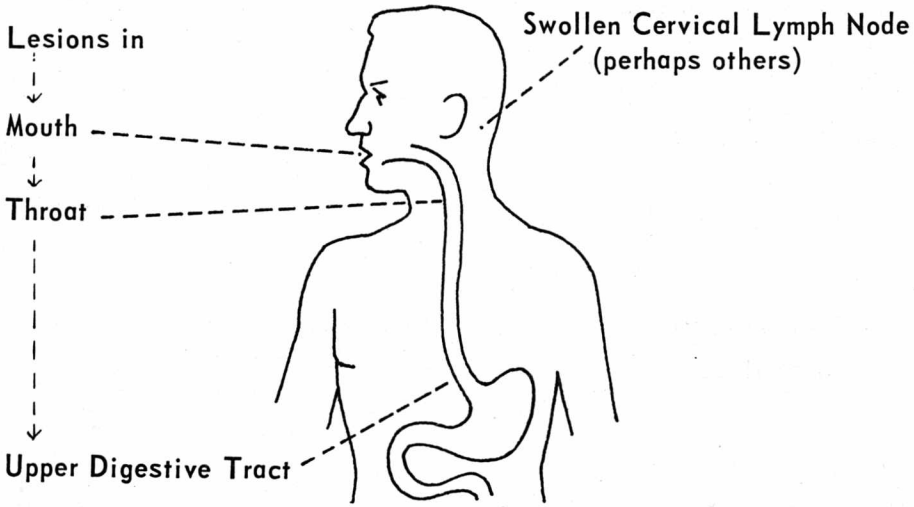
Oculoglandular Tularemia. Following contamination of the eye by the spattering of infected blood or by wiping the eye with a contaminated finger, the sequence of events is similar to that of the ulceroglandular type. Conjunctival ulcers and involvement of the cervical and preauricular lymph nodes occur. Oculoglandular tularemia is somewhat more difficult to manage than the ulceroglandular type.



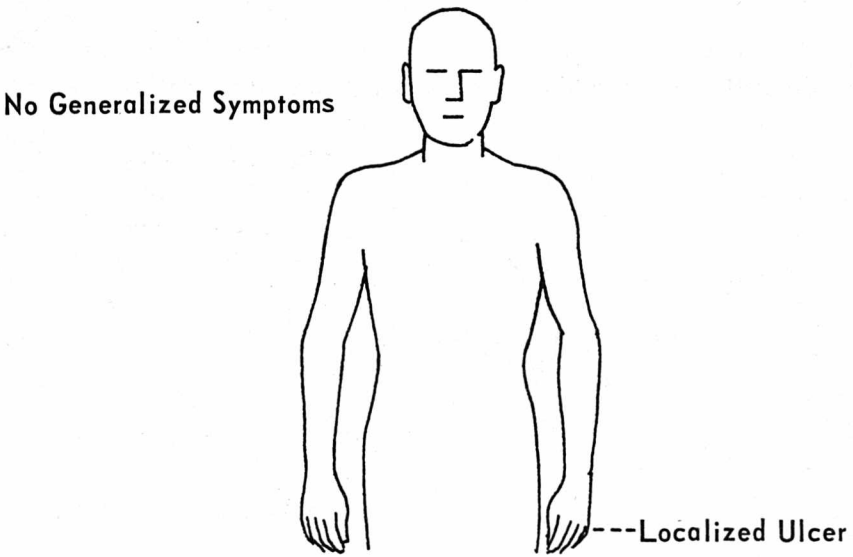
Pulmonary Tularemia. This type results from inhalation of infected material, such as the aerosols produced during the large scale dressing of rabbits, or the dusts containing crushed ticks and tick feces disseminated during the shearing of sheep. No primary lesions or buboes occur. This form of the disease is exceedingly difficult to manage and has a high fatality rate.



Ingestion (Typhoidal) Tularemia. Exposure by eating infected meat results in infections of the mouth, throat, and upper digestive tract. Local lesions may appear in the mouth. Regional lymph node involvement may occur. Ingestion tularemia, like pulmonary tularemia, is exceedingly difficult to manage and the fatality rate is high.



Immune-Reaction Tularemia. Exposure of a person who has recovered from tularemia to large concentrations of the pathogen can produce a localized reinfection which is an immune reaction comparable to revaccination with smallpox vaccine virus. A local tularemic papule develops which contains virulent pathogens, but the infection does not spread (Maxcy, 1956).



In the ulceroglandular and oculoglandular types of tularemia a primary ulcer, accompanied by regional lymphadenitis and lymphangitis, occurs at the site of infection. Involved lymph nodes frequently swell and resemble the buboes of plague. Focal and diffuse necroses with leucocytes, debris, and nuclear fragments as well as suppuration often occur.

The ulcer exhibits coagulation necrosis with nuclear fragmentation and polymorphonuclear infiltration. The base is infiltrated with small lymphocytes.

Focal necroses, with polymorphonuclear leucocyte and large mononuclear cell infiltration, occur in the liver, spleen, and lungs. If lobar pneumonia develops, a monocytic exudate occurs.

The spleen exhibits superficial and deep necrotic foci, containing amorphous material, nuclear fragments and a few leucocytes.

The liver usually exhibits necrotic hepatic cell foci. Early the area is filled with mononuclear cells, later with polymorphonuclear cells and nuclear fragments.

The lungs may exhibit small necrotic foci or white pleural plaques. Bronchopneumonia in all degrees may occur. Alveolar walls are infiltrated with edematous exudate and large mononuclears. Alveolar contents consist of a few red blood cells and leucocytes plus small amounts of fibrin.

In subacute stages of tularemia, the lesions of the primary ulcer, lymph glands, subcutaneous nodules, spleen, liver, lung, and adrenals may become granulomatous and resemble those of tuberculosis. The central necrosis is surrounded by radially arranged epithelioid cells and fibroblasts and a peripheral lymphocyte zone with a few giant cells.

Pasteurella tularensis rarely can be isolated from human tissues even though it possibly may persist in them for many years after apparent recovery from the disease. Morphologically recognizable forms are found only rarely in tissues of patients dead of the disease (Maxcy, 1956).

CLINICAL ASPECTS: PROGNOSIS

The fatality rates for tularemia are from 4.0% to 7.4% for all clinical types. However, mortality is much higher in pulmonary (up to 40%) and ingestion (up to 60%) tularemia than in the other clinical types.

If treatment with streptomycin or one of the tetracyclines is begun promptly and continued the recommended ten days, recovery is usually complete, although oculoglandular cases may be followed by visual loss due to corneal perforation and prolapse of the iris. Cases in which treatment is delayed or abbreviated may relapse.

In terminal cases, death usually occurs two weeks to nine months after onset of symptoms. Seventy-seven percent of terminal pulmonary cases expire the first month, 18% the second month, and 3% from the third to ninth month.

Non-terminal pneumonic cases show acute symptoms for 2 weeks to 5½ months; non-terminal typhoidal cases 2 weeks to 15 months.

Convalescence is slow, usually requiring 4 months, but a year is not unusual. During convalescence weakness, dyspnea, and fever bouts are usual.

There is evidence that *Pasteurella tularensis* remains in human tissues for many years after apparent complete recovery, but the carrier is not infectious.

Inborn resistance to tularemia has not been detected. A human can be infected intramuscularly by as few as 10 *Pasteurella tularensis* organisms or by inhaling 10-50 organisms.

An attack of tularemia produces effective immunity, but subsequent attacks can occur. Already described (under Clinical Aspects: Description) is immune-reaction tularemia where re-exposure produces localized reinfection comparable to revaccination with smallpox vaccine virus.

However, full-blown clinical cases can also recur (Green and Eigelsbach, 1950) (Van Metre and Kadull, 1959).

There is, apparently, only one antigenic type of *Pasteurella tularensis*. Excellent antibody production is stimulated in man as well as laboratory animals. Agglutinins have been shown to persist as long as 20 years.

Pasteurella tularensis has antigens in common with *Brucella melitensis* and *Brucella abortus* which has led some British workers to call it *Brucella tularensis*. Serum from rabbits immunized with *Pasteurella tularensis, Brucella melitensis,* or *Brucella abortus* may agglutinate the heterologous antigens in low titer.

More specific diagnostic sera can be prepared by absorbing the antibodies common to heterologus organisms.

Some patients may show high agglutinin titres to both *Pasteurella tularensis* and one of the *Brucella* species. Such a finding suggests that the patient may be suffering from an acute infection caused by one organism and that he had suffered a previous infection with the other.

Foshay's bacterial protein antigen injected intracutaneously into a patient with tularemia produces a slowly developing wheal which reaches its maximum size in 48 to 72 hours and persists five to six days. The test becomes positive during the first week of the disease and persists for life. A patient dying of tularemia may become anergic and will not respond positively to injection of the antigen.

Foshay's antibody serum test is performed by injecting hyperimmune anti-*Pasteurella tularensis* goat serum intracutaneously into the patient. It is imperative that the test be controlled by simultaneous injections of normal goat serum.

A positive test consists of the appearance of a wheal-erthymatous reaction within 15-20 minutes, disappearing in 30-60 minutes. A positive test indicates that the patient's body contains freely circulating antigens which combine with the antiserum at the site of the inoculation. No conclusions can be drawn if the normal serum and the hyperimmune serum elicit similar responses.

Agglutinins appear 10-14 days after infection. Agglutination titres of 1:20 or 1:40 are inconclusive but successive rising titres are diagnostic. Titres rising to 1:2560 to 1:5120 within 3 to 4 weeks are not unusual.

Active immunization is theoretically possible, and Foshay's detoxified antigen gives at least partial immunity. Foshay's killed tularemia vaccine prevents or modifies systemic infection but does not prevent local infection. It offers no protection against respiratory challenge. Viable attenuated vaccine has been demonstrated to be effective in preventing pulmonary tularemia.

"The frequency with which *Pasteurella tularensis* infects hunters of rabbits and laboratory workers studying this microorganism makes vaccination of these persons desirable" (Saslaw, *et al.*, 1961).

A large scale tularemia vaccination program has never been attempted.

ETIOLOGY: PATHOGEN

Pasteurella tularensis is a small (0.1-1 micron wide, 0.1-3 micron long), extremely pleomorphic bacillus. It is small enough to pass through Berkfeld filters (300-350 millimicron diameter).

The extreme pleomorphism is associated with young, actively growing colonies and does not represent involution forms associated with dying colonies.

The organism is gram negative and non-motile. It is aerobic and facultatively anaerobic. It reproduces by budding, binary fission, or filament formation. It is non-spore-forming. Some workers consider the organism to be non-encapsulated but to have an unusually thick cell wall which has been mistaken for a capsule. Others consider a capsule to be present.

Minimum, optimum, and maximum growth temperatures are 24°, 37°, and 39°C. Temperatures of 56°-58°C, for ten minutes, can be used for destruction of cultures.

Optimum growth is at pH 6.9 and the pH of the medium must be below 7.5 to insure growth. Since phosphate inhibits the organism, the pH of the medium should be adjusted with sodium hydroxide.

Pasteurella tularensis apparently produces no specifically identifiable exotoxin or endotoxin but proteins and lipoproteins of dead bacteria are toxic.

The organism does not grow on plain agar or plain bouillon media but grows well on blood-dextrose-cystine agar, blood-dextrose-cysteine agar, coagulated egg yolk medium, casein-biotin-blood-liver medium, gelatin hydrolysate-biotin-blood-liver medium, heart infusion-dextrose-cysteine-hemoglobin medium, and in the cells of the chorio-allantoic membranes and yolk sacs of chick embryos. Chemically defined media containing spermine also are used.

Thiamin can partially replace red cell extract in the first two media. Since cysteine (used as cysteine hydrochloride) is unstable it cannot be preserved longer than 3 weeks and only then with refrigeration. Freshly prepared media should be used and incubation in candle jars is recommended.

Transfer from culture to culture leads to avirulence. Transfer from egg to egg increases virulence for chicks. Virulence can be maintained by injecting glycerinated spleens (stored at -14°C) into guinea pigs each six months.

Colonies on blood-dextrose-cysteine (or cystine) agar after 24-48 hours are small, smooth, opaque, mucoid and butter-like. They are easily emulsified. Cultures should be transferred monthly and stored at 1-10°C (on blood-dextrose-cystine agar). Lyophilization will preserve viability up to 4 years. Infected animal organs stored in undiluted neutral glycerine will yield viable organisms after one month at room temperature, six months at 10°C, and six years at -14°C. Different organs should not be stored in the same container.

The organism is stained by routine gram stain procedures. Bipolar staining is not uncommon.

Growth is inhibited by sulfonamides, PABA, and as little as .15-2 micrograms of streptomycin per ml. of culture fluid.

Pasteurella tularensis gives irregular fermentation reactions.

Destruction of tissue emulsions can be accomplished by exposure to 1% tricresol for 2 minutes. Formalin (0.1%) kills organisms in tissues in 10 minutes at 56°-58°C, and cultures are killed after 24 hours exposure to formalin.

Gram negative
Non-motile
Pleomorphic

No spores
No endotoxin
No exotoxin

Min 24°C
Opt 37°C
Max 39°C

Opt pH 6.9
Max pH 7.5

animal ⟶ animal ⟶ animal = high virulence
colony ⟶ colony ⟶ colony = low virulence

Pasteurella tularensis

ETIOLOGY: DIAGNOSIS

A history of rabbit contact, tick bite, deer fly bite, or laboratory exposure in a patient with a severe infection is suggestive of tularemia.

Fluorescent antibodies can be utilized to (1) rapidly screen cultures, (2) detect tularemia organisms from peritoneal exudates, lesions, etc., and (3) detect *Pasteurella tularensis* in impression smears of tissues, whether or not these tissues have been formalinized or paraffinized. A modification of this technique can be used to detect serum antibodies. Because of its speed and specificity the FA technique is probably the diagnostic method of choice.

Cultivation of *Pasteurella tularensis* from infected material is difficult. Blood, primary lesions, material aspirated from softened lymph nodes, and sputum can be used as inocula. Blood-dextrose-cystine agar streaks can produce characteristic colonies in three to five days but, if colonies do not appear, cultures should be observed for at least three weeks. Isolated colonies may be identified by specific agglutination.

The patient's serum may be tested for agglutinins, a 1:80 titer being diagnostic if not cross reactions with *Brucella* antigens occur. If *Brucella* agglutinins are found, the tularemic patient will exhibit a higher agglutination titer with *Pasteurella tularensis*.

Intraperitoneal inoculation of a mouse with 0.1 to 0.2 of a light saline emulsion of infected material will produce characteristic lesions and death within 1-6 days.

The characteristic lesions include (1) hemorrhagic edema without pus at the site of the inoculation; (2) enlargement of cervical, axillary, and inguinal lymph nodes which, upon autopsy, contain dry caseous material; and (3) small white necrotic areas in the liver and spleen.

Differentiation from plague, which resembles tularemia clinically, is made by serology, staining characteristics, organism size, the regular fermentation patterns of *Pasteurella pestis,* and the reaction to specific bacteriophage.

The cross agglutination with *Brucella abortus* and *Brucella melitensis* may be misleading and should be kept constantly in mind.

EPIDEMIOLOGY: GENERAL

Pasteurella tularensis is an extremely infectious bacterium with a wide range of hosts and habitats.

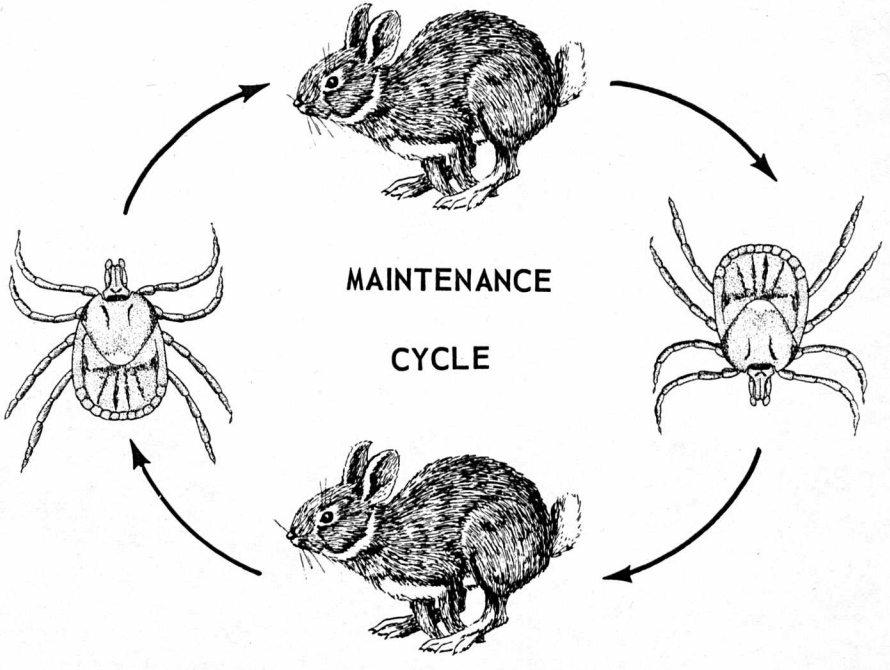
Tularemia is transmitted primarily by the bite of infected ticks or deer flies, and by direct or indirect inoculation of the skin or conjunctival sac through skinning, dressing or otherwise handling infected mammals, ticks, or deer flies.

Ingestion of insufficiently cooked infected meat can result in tularemia as can the drinking of contaminated water, the bite of a carnivore which has been feeding on infected animals or the shearing of sheep, which raises an aerosol of infected tick fluids and feces.

One case has been reported which apparently involved man-to-man mechanical transmission. Laboratory infections are not uncommon.

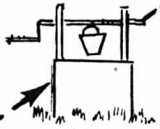
In time of "disaster" – natural, economic, or as the result of military aggression – the widespread enzootic of tularemia in the United States could produce large numbers of human cases (Scott, 1964).

In the event of mass evacuations to temporary or semi-permanent relocation sites, tularemia would be a constant hazard to people evacuated from relatively disease-free areas to tularemic areas.

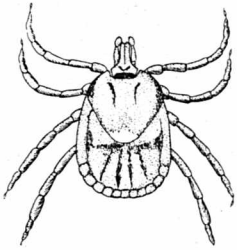


Tick Bite

Man Drinking Water

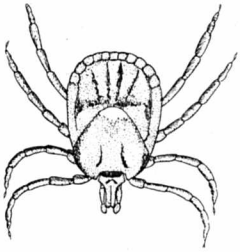


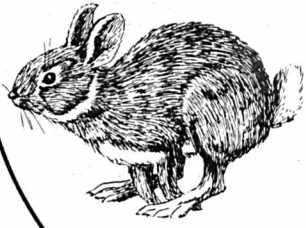
Water Supply



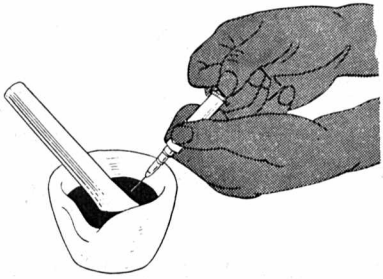
MAINTENANCE

CYCLE

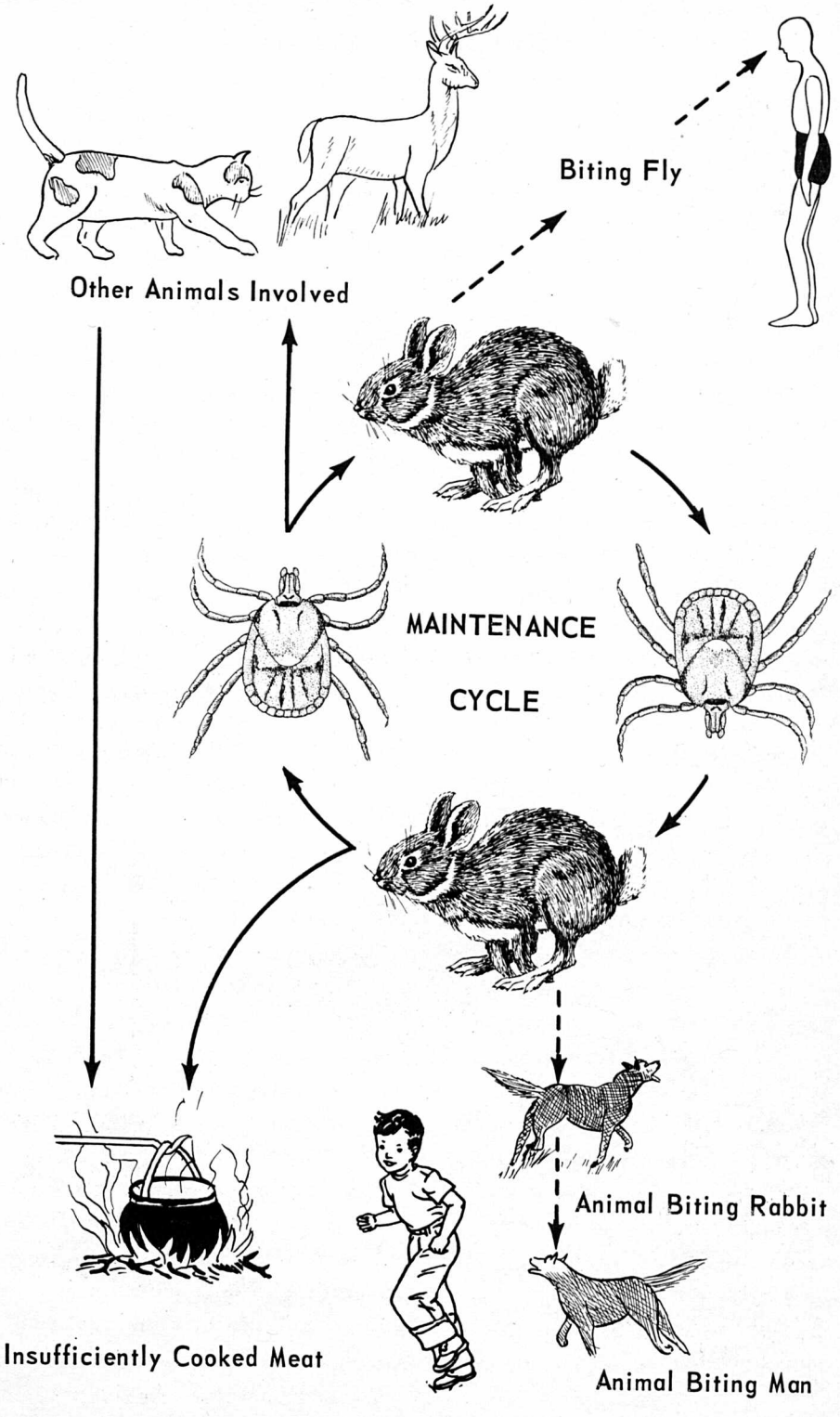




Contact



Laboratory Accidents


Biting Fly
Other Animals Involved
MAINTENANCE
CYCLE
Animal Biting Rabbit
Insufficiently Cooked Meat
Animal Biting Man

About 70% of the human cases of tularemia in North America result from contact with hares and rabbits. However, in Arkansas more than 50% of the cases are associated with ticks (Washburn and Tuohy, 1949). Rabbits (*Sylvilagus*), particularly the eastern cottontail (*Sylvilagus floridanus*), are the direct source of over 55% of all human cases of tularemia. Less than 40 (0.3%) of the 14,000 reported cases occurred beyond the known range of rabbits. Tularemia is rare in New England; *Sylvilagus floridanus,* the eastern cottontail, extends into Connecticut and Massachusetts but not into the other New England States. Jack rabbits (*Lepus*) are known reservoirs and the source of a few human cases. These rabbits are of greatest importance as a source of infection for ticks and deer flies which later bite and infect man. The varying hare (*Lepus americanus*) has been found naturally infected, but is highly resistant and few human cases have resulted from contact with these hares. Tularemia strains from *Sylvilagus* are highly virulent, while those from *Lepus* are only moderately virulent (Jellison and Parker, 1945; Burroughs, *et al.,* 1945).

Meadow voles (*Microtus*), muskrats (*Ondatra zibethica*), and beavers (*Castor canadensis*) are involved in the epidemiology of water-borne tularemia. A few human cases may have resulted from skinning muskrats and beavers, but the main role of these rodents seems to be the contamination of soil and water from which human cases have originated (Jellison, *et al.,* 1960).

Natural infection occurs in every month of the year. In the West it is most prevalent in the summer, while in the East it is most prevalent in the winter. In the western States, ticks are particularly dangerous from March to August, deer flies from June to September, jack rabbits from April to October. In the eastern States most human infections occur from November to January, the months when cottontails are hunted (Herms, 1953; Calhoun, 1954).

The key factor in transmission is the tick population which keeps the infection spreading in the wild mammals (Leporidae, Cricetidae, Sciuridae, and Castoridae). Probably only a few of the many naturally infected animals serve as key reservoirs in any environment.

Tularemia is usually fatal to infected rodents and rabbits, thus, the continuation of the disease through these carriers or reservoirs

seems unlikely, and both groups of animals are probably regulatory in this manner.

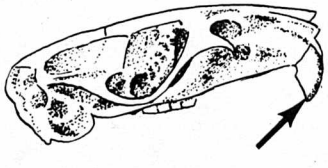
Both rabbits and rodents have an extensive bacteremia prior to death from tularemia infection. Any ectoparasites feeding during this time may obtain an infectious blood meal and thus may become potential vectors (Anonymous, 1960; Simmons, Stevens, and Reeves, 1953).

Tularemia can be transmitted from rodent to rodent by cannibalism in areas of high population density during the winter period when ectoparasites such as ticks and fleas are quiescent. Although cannibalism among rodents is a well known characteristic, it does not occur normally except in abnormally high populations where food is limited (Kartman, Prince, and Quan, 1959). Carnivores sometimes acquire tularemia by feeding on infected rodents, rabbits, or hares.

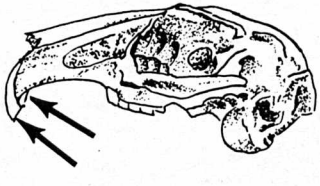
An increased incidence of tularemia in humans usually coincides with an increase in the infected rodent and lagomorph population; human disease usually does not occur until at least one percent of the wild mammals in the region are infected.

Hares, Rabbits, and Conies – Order Lagomorpha

Lagomorphs can be distinguished from rodents by the possession of two pairs of upper incisors, the second pair directly behind the first. Only one family of this order, Leporidae, is important in tularemia transmission to man.



Rodent



Lagomorph

Hares and Rabbits – Family Leporidae

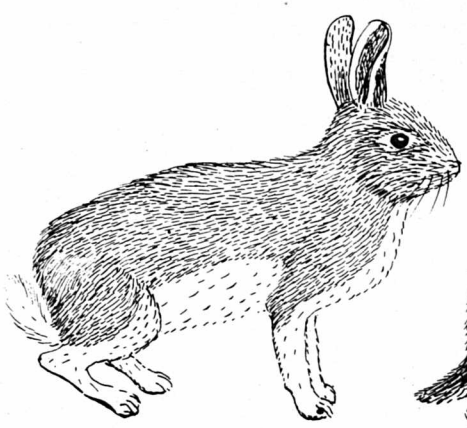
Two obvious characters distinguish this family: the hind legs are longer than the front; and the ears are longer than wide. Females are usually larger than males. The reverse is true in most other families of mammals.

"Hare" is the name applied to those lagomorphs whose young are born fully haired, with the eyes open, and able to run about within a few minutes after birth. The young are born in the open, not in a nest. Hares belong to the genus *Lepus*.

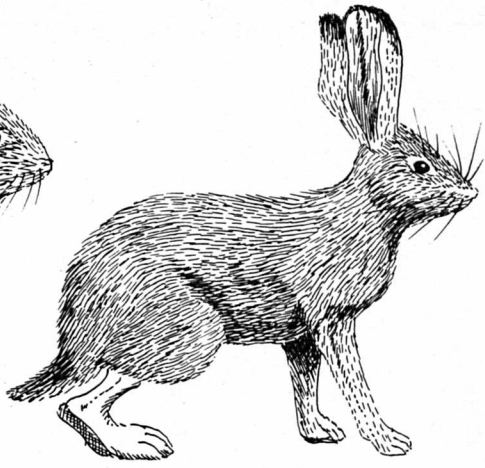
"Rabbit" is the name applied to those lagomorphs whose young are born naked, blind, and helpless, in a nest built for them and lined with fur. Rabbits belong to the genus *Sylvilagus*.

Hares and rabbits are found throughout North America, although hares are more northern and western in distribution, whereas cottontail rabbits and related species are more southern, being found throughout the United States, but extending into Canada only a short distance.

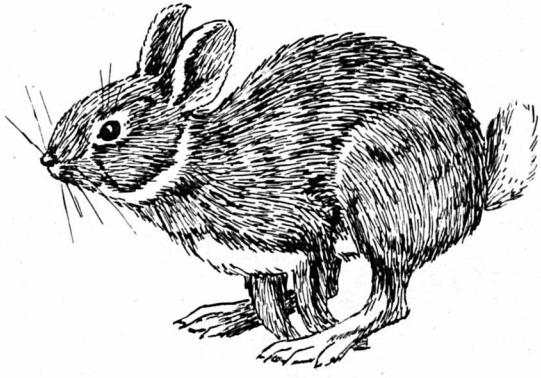
Hares and rabbits have a high population potential although not as great as that of mice. They are crepuscular and possibly more nocturnal than diurnal. They do not store food or hibernate. Hares and rabbits are preyed upon by almost every flesh-eating snake, bird, and mammal. They are hosts to a great variety of ectoparasites: ticks, fleas, lice, and mites.



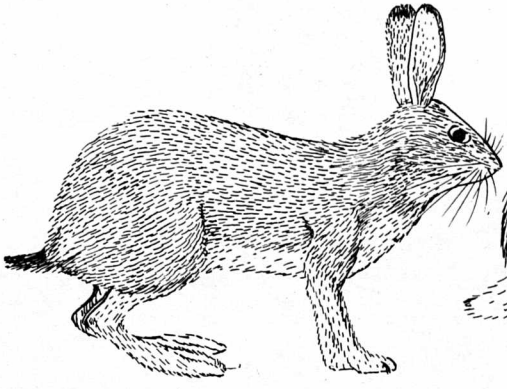
Sylvilagus audubonii
Desert Cottontail



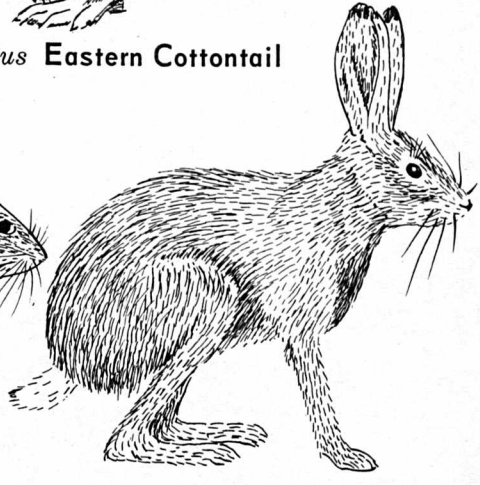
Lepus californicus
Black-tailed Jack Rabbit



Sylvilagus floridanus **Eastern Cottontail**



Lepus americanus
Snowshoe Rabbit



Lepus townsendi
White-tailed Jack Rabbit

Rodents – Order Rodentia

Because of their great numbers and variety, rodents are of incalculable importance to man. Many serve as buffer species; they are a source of food for predators and absorb much of the predator pressure that would otherwise be directed against more desirable species. The food habits of many rodents make them highly desirable from man's viewpoint because they destroy many noxious weeds and insects. Feeding habits at times make some rodents in localized areas serious and expensive nuisances. The activities of rodents are beneficial to man on the whole; and control activities, when required, should be pursued with discretion and knowledge.

Rodents are preyed upon by almost all flesh-eating reptiles, birds, and mammals. Rodents are host to many ectoparasites: ticks, mites, fleas, and lice infest the skin and fur, while kissing bugs infest the nests of some rodents.

Squirrels – Family Sciuridae

This family includes digging, ground-living, tree-living and gliding species. The members of this family are widely distributed and remarkably versatile ecologically. Although primarily herbivorous, nearly all squirrels will accept animal food occasionally, and some do so avidly. The members of this family have only moderate reproductive potentials.

Citellus beecheyi

California Ground Squirrel

Ground squirrels (*Citellus*). Ground squirrels are found mostly in western North America, except the thirteen-lined ground squirrel, which extends into middle North America.

Ground squirrels seldom leave the ground. They become extremely abundant under favorable conditions, and are very destructive when they occur in agricultural districts. Ground squirrels are reservoirs of plague, tularemia, spotted fever, relapsing fever, and Colorado tick fever.

Ground squirrels obtain needed water from succulent green vegetation. When vegetation dries and seeds mature, most species hibernate or aestivate until green vegetation is available. The young of species that aestivate or hibernate may remain active for several months after the adults have gone to their dens. The adults emerge several weeks before the young in the spring. Ground squirrels are not sociable.

Chipmunks (*Tamias and Eutamias*). Chipmunks dig their own burrows, build a large nest of dry plant material at the end of a tunnel, store food in the summer and autumn, and are active for a part of the winter in some places although some individuals hibernate. Principal foods are nuts, seeds, and fruits, although some animal matter is eaten. They are active during the day.

Chipmunks are distributed over most of the United States where suitable habitat exists, except the low hot desert of the Great Plains and the Lower Colorado River drainage. The ranges of the eastern chipmunk and the western chipmunks do not overlap, except for a small area around the Great Lakes.

The western chipmunks (*Eutamias*), with one exception, are smaller, more streamlined, and have a comparatively longer tail than the eastern chipmunks (*Tamias*).

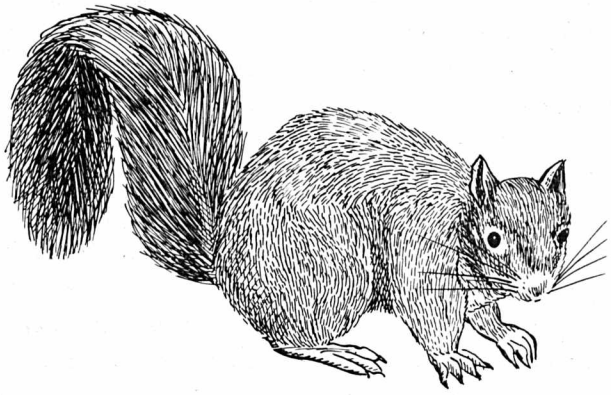
Eutamias minimus

Least Chipmunk

Tree squirrels. The tree squirrels have hand-like feet with long flexible toes which have sharp, strong claws adapted for clutching the rough bark of a tree. All have a bushy tail which is used to break the force of falls and as a balancing organ.

Tree squirrels feed on bark, leaves, fruits, fungi, insects, birds, and other animal life. All tree squirrels store food. Nuts are the chief item, acorns, beechnuts, and hickories being the most important.

Tree squirrels prefer to build their nests in which to bear their young in hollow trees. All build leaf nests in the summer for sunning or to escape ectoparasites when they become too annoying in the nest.



Sciurus niger
Fox Squirrel

Native Rats and Mice – Family Cricetidae

The native rats and mice comprise the largest family of North American mammals, ranging in size from the tiny harvest mouse to the muskrat, with many species of diverse food habits. All are essentially omnivorous, although adapted for the most part to a vegetable diet. Many are of considerable economic importance, being destructive to agricultural crops. The family is divided into two subfamilies, the Cricetinae and the Microtinae.

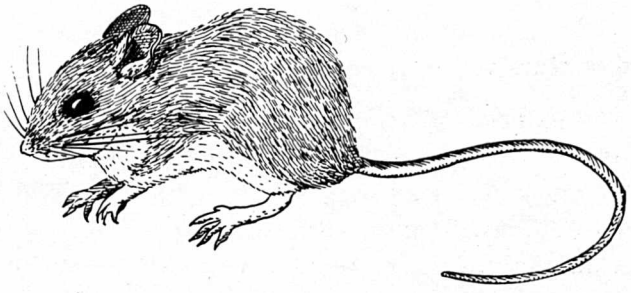
Cricetinae

The Cricetinae are small to medium-sized terrestrial rodents with long tails, large ears and eyes, four toes on the front and five toes on the hind feet. They are slender to thickset with pointed muzzles; limbs are not hidden to any marked extent. This subfamily contains 21 genera, of which only seven – *Peromyscus, Neotoma, Reithrodontomys, Oryzomys, Sigmodon, Onychomys,* and *Baiomys* – occur in the United States.

These rodents have a tremendous breeding potential: they breed during most seasons of the year, have many litters, and have many young in each litter.

Deer and white-footed mice (*Peromyscus*). The deer and white-footed mice are among the most widespread and geographically variable of North American rodents, being found in almost every possible habitat. In most places within their geographical range these mice are the most abundant mammals. The large number of species and the geographical variation in most species makes identification of these mice most difficult. The color and color pattern is variable: some species are nearly white and others nearly black; some are unicolor and some sharply bicolor. In most species the upper parts are conspicuously darker, and more richly colored, than the under parts.

Deer mice eat a wide variety of food: almost anything edible is accepted at least under some conditions. In turn, they are among the principal prey species in North America, and as such are a principal buffer species for valuable game and fur-bearers.



Peromyscus maniculatus
Deer Mouse

Wood rats (*Neotoma*). Wood rats are large ratlike mammals with large ears, large beady eyes, and a fairly long tail which is sparsely covered with hairs or well furred with long hair, depending upon the species. Their fur is long and soft: dorsal color cinnamon, brown, gray, yellowish gray, or creamy buff; feet and ventral parts white or creamy white; tail blackish or buffy, paler on ventral surface. Females are about a fifth smaller than males. Wood rats are much larger than mice; the uniform coloring distinguishes them from any ground squirrels that are the same size; and the soft, well-haired ears, and clean habits distinguish this native species from the domestic rat.

Wood rats are found over much of the United States. Their dens may be six feet in height on the ground, 20 feet up in trees, or a long roofed-over ditch in the ground. A house in a good foraging spot will be cccupied for many years. Wood rats live alone except when mating or rearing young, occupying one den throughout the year, and generally for a lifetime.

Wood rats seem to have small home ranges under ordinary circumstances, often restricted to less than 50 feet in any direction from the den, to which it is definitely attached. Their food consists of vegetable matter which varies widely with the region as well as with the season of the year: they eat what is available within 50 or 100 feet of their den; mostly seeds, nuts, acorns, and berries; quantities of leaves of shrubs; and entire plants of small annuals.

Wood rats live in several different types of habitats, generally among rocks because of the protection offered.

Neotoma fuscipes
Dusky-footed Wood Rat

Microtinae

The subfamily Microtinae contains nine genera (two in the Arctic only) which vary in length from 4 to 24 inches. These are thickset animals with rounded muzzles; most of each limb is hidden in the skin of the trunk, thus resulting in a short-legged appearance; five toes on each foot; tail never as long as head and body. They occur throughout North America.

The members of this subfamily, like the Cricetinae, have a tremendous breeding potential: most breed throughout the year; many litters are born each year; and each litter contains many young.

Meadow voles (*Microtus*) are medium sized, stocky, with small eyes and ears, and a short tail well covered with short hair. The fur is loose, rather long, blackish, grayish brown or yellowish brown heavily sprinkled with black hairs resulting in a grizzled appearance; darkest on the back and shading into gray, ashy, or buffy on the under parts. The feet are not grizzled. The tail is dusky above, slightly paler below.

The meadow voles and other American voles are the busiest mammals north of Mexico: They rush about by day and night, taking only a few hours for sleep, while finding and eating their own weight in food every 24 hours. Families are born and reared in a rush; young females can mate when less than four weeks old. Their lives are short, usually less than a year.

Meadow voles (*Microtus*), sagebrush voles (*Lagurus*), pine voles (*Pitymys*), redback voles (*Clethrionomys*), tree mice (*Phenacomys*), and bog lemming mice (*Synaptomys*) are often called "field mice:" all are similar in appearance and habits, thus all are included under the general term "meadow voles." Since they are so similar in appearance, it is usually neces-

Microtus pennsylvanicus
Meadow Vole

sary to use tooth and skull characters to differentiate the species. There are 33 species found north of Mexico: each is adapted for a particular serological niche anywhere between sea level and timber line, throughout North America. They are highly important whenever they exist: to man, because of their enormous appetites; to carnivores, because of their food value.

Food, cover and other necessities permitting, meadow mice ordinarily number up to about 50 per acre. Microtine populations (*Microtus* and *Pitymys*) are cyclic: The population reaches peak numbers approximately once every four years and then abruptly dies back to a condition of relative scarcity which lasts for about two years, to be followed by another breeding surge. A population four to six times the usual is common during these peaks; disease finally stops these eruptions, the mouse populations disappear rapidly within three or four months and after six months it is difficult to find a vole.

Muskrat (*Ondatra zibethica*). Muskrats resemble huge meadow voles and are about the size of a small house cat; uniformly dark brown on the upper parts, silver tipped on the belly. They have small beadlike eyes, and the ears are nearly concealed in the dense fur. The hind feet are large, with webs between the toes. The black, scaly, nearly naked, laterally flattened tail is about as long as the head and body.

Muskrats are found from the Atlantic to the Pacific, and from the Gulf of Mexico to the Arctic Ocean. Their habitat consists of marshes, ponds, lakes, and streams, especially where there are heavy growths of rushes or cattails. They are chiefly aquatic. Open water, at least part of the year, is essential. Most muskrats build large houses of available

Ondatra zibethica
Muskrat

vegetation. Some muskrats, along streams or where water is low, burrow into banks and do not build houses.

The food of muskrats consists chiefly of stems and roots of aquatic vegetation. In an emergency they will eat almost any available plant food. Mussels, frogs, turtles, and fish, as well as their own kind, are eaten on occasion.

The home range of an individual muskrat is less than 200 yards in diameter. Muskrat populations are cyclic: muskrats may number as many as 10 to an acre, or they may be very scarce. Bad weather, floods, droughts, and epidemics affect their numbers.

The muskrat is an important fur animal. It usually occupies wasteland and does no damage to man except when it burrows into dikes and causes them to wash out. It is important as a reservoir of water-borne tularemia.

Beaver – Family Castoridae

This family contains only one genus, *Castor,* the beavers. These are large, aquatic rodents.

Beaver (*Castor canadensis*). This is the only species of the genus in North America. Beavers are the largest rodent north of Panama, many adults weighing more than 60 pounds. Their body, 25 to 30 inches long, is thickset and compact; legs short; ears small; hind feet large, 6 to 7 inches long, webbed with a double claw on the second toe. The 9- to 10-inch long tail is scaly, broad, and flattened horizontally. The beaver looks like a huge muskrat, but the broadened tail is a distinctive mark at all ages. The upper parts are a rich glossy brown; under parts brown to tawny; feet and tail black. Their fur is very valuable.

Castor canadensis
Beaver

Beavers are distributed over most of North America. Their habitat consists of streams and lake shores bordered by stands of

small timber, preferably aspen, popular, birch, maple, or willow. A dam of sticks, stones and mud is constructed to impound water and form ponds. Beavers construct and live in dome-shaped lodges made of sticks and mud. Beavers do not build lodges in rivers or swift flowing streams, but burrow into banks. From one to several families live in one lodge and there are often many lodges in a colony. Defense of territory by a colony of beavers has been observed. More than one colony may occupy a large lake or pond, but there is little overlapping of colonies. Two colonies may share in keeping a dam in repair, but there is no trespass on the feeding areas and lodges.

Food consists of bark and cambium, especially of willows, alders, birches, and aspens. The individual range is small for such large animals; they usually do not travel more than a half mile from their lodge: unmated beavers seeking a mate or a good location may travel for 10 to 12 miles or more.

A pair of beavers mate for life: a beaver may live for 11 years or more in the wild. The mating season is January or early February. The young are usually born in April or May. A litter consists of 2 to 8 kits, usually 4. There is but one litter per year. Beavers are susceptible to water-borne tularemia.

Other Mammals

Other animals besides rodents and lagomorphs have been found naturally infected with tularemia. Those in addition to the mule deer and grouse are:

Insectivores

Sorex vagrans	wandering shrew

Carnivores

Urocyon cinereoargenteus	gray fox
Vulpes fulva	red fox
Procyon lotor	raccoon
Mephitis mephitis	striped skunk
Spilogale putorius	eastern spotted skunk
Taxidea taxus	badger
Lynx rufus	bobcat
Felis domestica	domestic cat
Canis familiaris	domestic dog

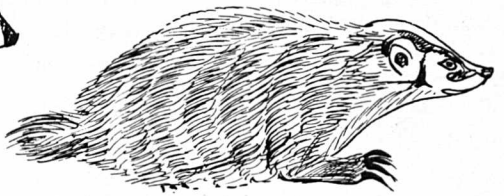
Marsupials

Didelphis marsupialis	opossum

Artiodactyls

Ovis aries	sheep

Procyon lotor
Raccoon



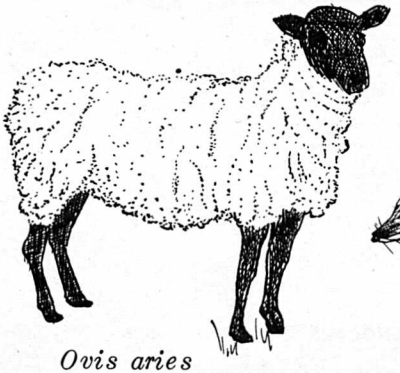
Taxidea taxus
Badger

Mephitis mephitis
Striped Skunk

Didelphis marsupialis
Opossum

Sorex vagrans
Wandering Shrew

Canis familiaris
Domestic Dog



Ovis aries
Domestic Sheep

Vulpes fulva
Red Fox

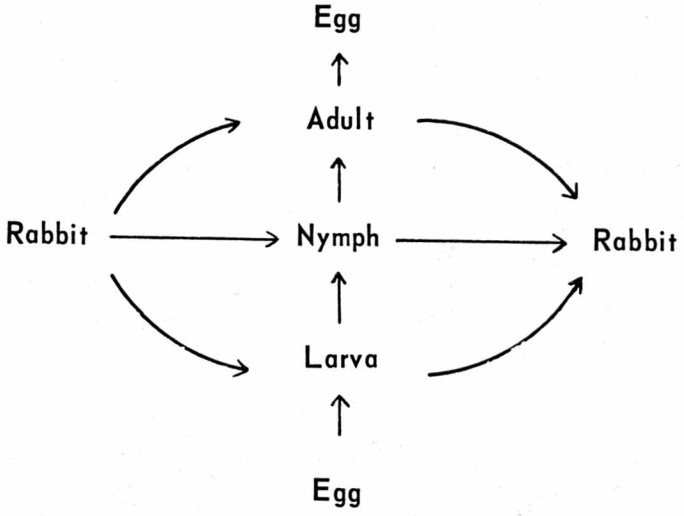
EPIDEMIOLOGY: TICKS

Ticks are known to transmit a number of disease agents belonging to the viral, rickettsial, bacterial and spirochaetal groups. Although patterns of transmission may vary between tick species as well as pathogen species, there are certain basic epidemiologic aspects (generalized patterns) relating to tick-borne disease which are applicable for consideration under most situations. A knowledge of such patterns assists in placing tick-borne disease in its correct perspective and in turn such perspective enables better program planning and execution for preventive medicine (Arthur, 1962).

Tick Transmission of Pathogens

Pathogens ingested by the tick establish themselves in the epithelial lining of the midgut and also penetrate the intestinal wall to be carried by the open circulatory system to most organs of the body. The blood of arthropods (hemolymph) is contained within a single cavity and freely bathes all tissues. Therefore, all organs (including the gonads and salivary gland) are subject to infection.

Infection in the gonads permits transmission from tick to offspring (vertical transmission), and infection of the salivary gland greatly enhances transmission to vertebrate hosts (horizontal transmission) since salivary gland infection means that the pathogen can be inoculated into the host (McDowell, 1964).



Vertical Transmission = Within one species

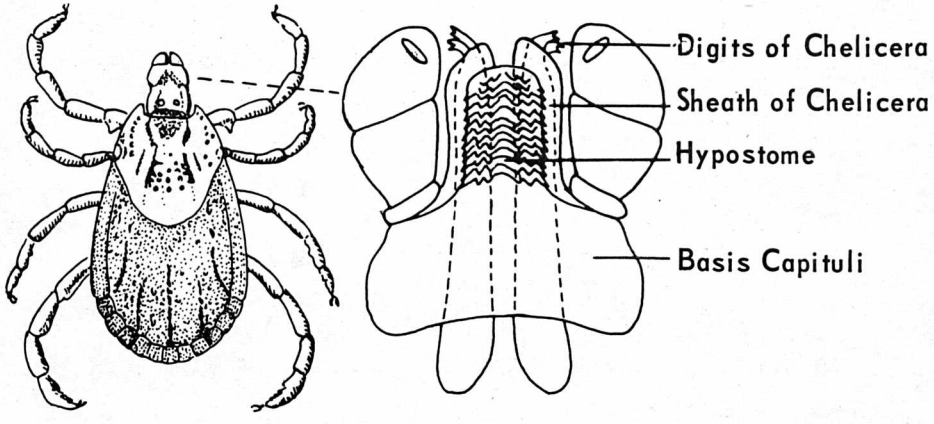
Horizontal Transmission = Up or down the phylogentic scale

Inoculative Transmission

The mouthparts of the tick are short and therefore cannot readily penetrate a capillary or capillary bed. After the mouthparts are inserted into the host, lytic substances and anticoagulants are secreted. The lytic substances digest tissue cells and capillary walls. Tissue cells as well as blood cells are imbibed by the tick. Some ticks may fill one-third of capacity on tissue fluids before obtaining blood.

Arthropod vectors transmit pathogens to a host by two means, inoculation and contamination. Inoculative transmission is by far the most important for the maintenance of a disease cycle, since the secretion of salivary juices is sure to occur as the vector feeds on the host. Contaminative transmission is less likely to occur since it depends upon the chance of contaminated material such as excreta or other body substances coming into direct contact with the wound.

Horizontal transmission of pathogens by ticks is both inoculative and contaminative.



Dermacentor Mouthparts

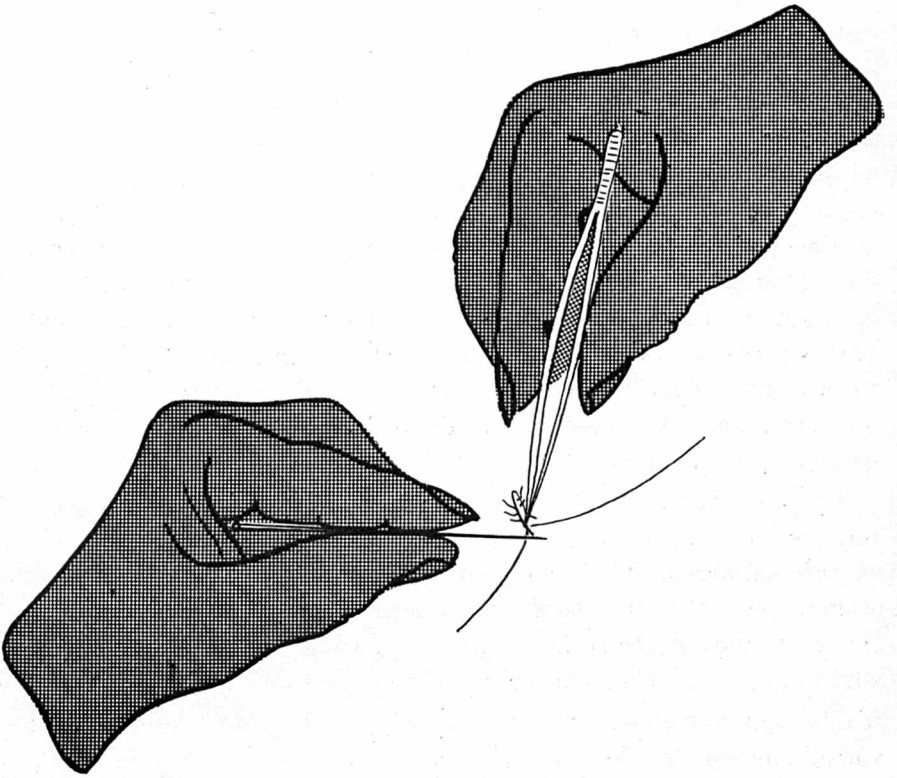
Because of the time needed to insert its mouthparts and to digest capillary walls, a tick may not immediately acquire or transmit a blood pathogen. Therefore, early removal of an attached tick by correct methods may prevent infection. Conversely, incorrect methods of removal can produce infection.

Contaminative Transmission

In the tick the presence of pathogens in the intestinal tract, hemolymph and coxal glands (soft ticks only) may play an important role in contaminative transmission. An infection acquired from the intestinal tract of a tick may occur in two ways. When a tick is carelessly removed from the host very often the mouthparts are left imbedded in host tissues. The separation of the mouthparts from the tick will rupture the intestinal tract resulting in the release of gut contents around the wound. Infection by this means is avoidable. Tick feces may also contribute to infection, especially for such highly infectious organisms as *Pasteurella tularensis*. Many infections among personnel responsible for sheep shearing have been attributed to the handling of wool grossly contaminated with crushed ticks and tick feces. Some workers even consider that the inhalation of tick feces may account for some of the pulmonary complications deserved in tularemia (Jellison and Kohls, 1955).

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

Infection from the hemolymph (a carrier of pathogens as well as an excellent culture media) may also be acquired in two ways. In both hard and soft ticks any activity which would crush the arthropod against the host could liberate pathogens which could enter through the wound.

Ticks as Reservoirs of Pathogens

The maintenance and spread of pathogens within the tick population is, in part, dependent upon a number of factors relating to the tick and pathogen.

The **transovarial passage** (i.e. from tick to offspring) of pathogens may or may not be a major factor in the maintenance of infection within a tick population. The exact importance of such passage varies between species of tick and between types of pathogens.

For some tick-borne virus infections it has been estimated that the efficiency of transovarial transmission is of the order of 10% or less. An efficiency of this low order coupled with the fact that only several of the one thousand or more eggs laid by the infected female ever develop to adult ticks, would indicate that pathogen maintenance was more often dependent upon factors other than transovarial passage.

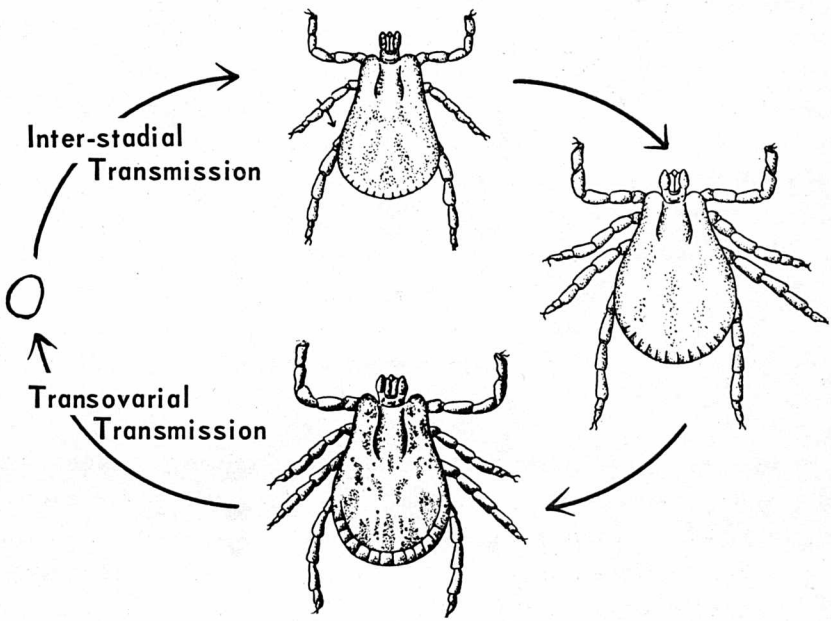
On the other hand, in some species of ticks transovarial passage may be one of the major explanations for maintenance and spread of the pathogen. The one host tick develops from larval to adult stages on only one host and therefore has little opportunity to spread infection from host to host during the larval, nymphal or adult stages. In this case the maintenance and spread of infection within the vertebrate hosts can only be brought about by transovarial passage of the pathogen in the tick. The engorged adult tick drops off the host and lays infected eggs which hatch to produce larvae which in turn will seek out new hosts.

Transovarial passage could supplement horizontal transmission or in the absence of a suitable infected host, be responsible for indefinitely maintaining the infection in a tick population. Transovarial passage could also be significant for starting new lines of infected ticks and distributing pathogens widely in a tick population (i.e., the infected male may fertilize several females).

Transovarial passage could supplement horizontal transmission or, in the absence of a suitable infected host, be responsible for indefinitely maintaining the infection in a tick population. Transo-

varial passage also could be significant for starting new lines of infected ticks and distributing pathogens widely in a tick population (i.e., the infected male may fertilize several females).

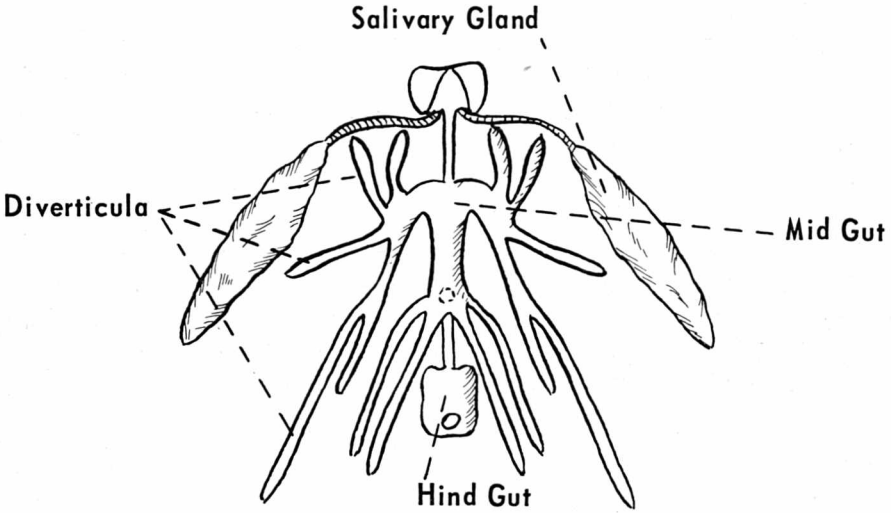
Inter-stadial passage, the ability for an infection acquired during the larval or nymphal stage to be passed on to the next developmental stage, is important in maintaining as well as distributing the pathogen. It is of particular importance in the distribution of infection to vertebrate hosts. A three host tick (one in which each developmental stage feeds on a separate vertebrate host) could be responsible for infecting up to three hosts if transovarial passage occurs.



Another factor contributing to the maintenance of pathogens within the tick population relates to the inherent ability of the tick to survive.

Opening into the midgut of the tick are a number of blind sac-like diverticula. As the tick engorges, the midgut and diverticula fill with blood and will stretch to such an extent that the hemocoelic cavity is almost obliterated. It is these diverticula which permit the storage of food for long periods of time and thus permit the tick to overwinter without feeding and also to survive prolonged periods of starvation. In general, for a three host tick the larval and nymphal

stages usually have to feed within a year, however, the adult can usually survive for two or three years in the face of adversity. This ability to survive enables the pathogen to overwinter as well as maintain infection for long periods of time in the absence of a suitable vertebrate host.



Hard Tick Internal Anatomy

It is well to remember that the inherent factors just described as well as the experimental suitability of ticks for infection may apply to many tick species other than the particular one or two primarily responsible for maintaining the infection in an animal population. The maintenance tick species may be found in association with other species. However, the maintenance species differs from others in that it occurs in significant population density and has biting preferences and behavior which permit feeding on the maintenance vertebrate hosts with sufficient frequency to maintain transmission.

Factors Affecting Tick-Borne Disease Infection Rates

Since the tick withstands infection very well, transmits pathogens vertically as well as horizontally, and has sufficient longevity to infect several generations of susceptible rodent hosts, it would appear that the rate of infection among ticks and vertebrate hosts would progress to such an extent that all ticks and hosts would soon

be infected. However, as investigations have shown, such is not the case. In some instances where collections and examinations have followed a consistent pattern over a period of years it has been shown that infection rates vary between collecting sites and according to season. In some instances the infection rates encountered have been of such a low order as to make it difficult to identify the maintenance vertebrate host or tick.

The phenomena which would bring about a "natural braking force" on transmission are in most cases imperfectly known. However, two aspects have to some degree been investigated. One has to do with **duration of infectivity** for tick and vertebrate host and the other has to do with **host immunity.**

The tick can maintain infection throughout its lifetime, however, the duration of tick infectivity to a vertebrate host may be limited by several factors. Where transovarial passage is important in maintaining infection, continued passage without infection from an infected vertebrate host may alter the pathogen in such a way that it is no longer infective. Another, and perhaps more common factor relating to infectivity, is the depletion of pathogens in the tick. For some types of infection it has been proven that feedings taken by the tick after the infecting meal will deplete the number of pathogens in the salivary glands. This depletion may extend to the point that the bite is no longer infective.

The duration of host infectivity is more fully understood than the duration of tick infectivity. In some instances the recently infected host will only develop a sufficiently high level of pathogens in the blood to infect ticks for a period of several days or a week. Parasitemia of this short duration reduces the probability of ticks acquiring an infective blood meal.

Host immunity may serve as a "braking force." For example, an infective tick with only so many blood meals left to complete its life cycle feeds on an immune host. The host does not develop sufficient parasitemia to be infective to a susceptible tick. Therefore, one infective dose is lost to the further dissemination of infection. In addition, the antibodies from the host's blood can exert a considerable influence on the infection in the tick. There can occur either a decrease in number of pathogens or the pathogens can be completely neutralized thus rendering the tick non-infective.

Factors Governing Distribution of Tick-Borne Disease

The long-term maintenance and circulation of tick-borne pathogens in nature depends basically on one of a limited number of vertebrate hosts and their associated ticks termed maintenance hosts. The vertebrates are ground-frequenting mammal and bird species. Such hosts (1) are wild rather than domestic, (2) do not usually exhibit marked symptoms of disease although the pathogen circulates and antibodies are formed, and (3) have a high and rapid fecundity thus providing sufficient susceptible young to keep the infection going. The circulation of pathogens between individuals of the maintenance vertebrate species depends essentially on the maintenance of a tick species whose population density as well as preference for the vertebrate host is sufficient to maintain infection.

Where pathogens, tick vectors and natural vertebrate hosts form associations within which the pathogen circulates and is maintained, it is termed a **natural focus of disease.** This natural focus usually has no direct associations with man. Its maximum geographical range is determined primarily by the distribution of its tick host or hosts although the availability of sufficient numbers of susceptible vertebrates capable of pathogen maintenance is also essential. Within this broad geographical range the actual occurrence of the tick species and therefore the potential for transmission may be extremely patchy. The reason for this is that vegetation, cover and climate is not favorable everywhere for the survival of ticks. A microclimate, consisting of the correct height and type of vegetation and suitable temperature and humidity are the most important factors in determining whether the tick can survive and find a suitable host.

Durability of Natural Foci

Since the longevity of the infected tick is sufficient to enable infection of at least several generations of vertebrate host (i.e., the continuing availability of susceptibles and exposure to infection is ensured) and since ticks are limited in their range of movement and areas of suitable microclimate are patchy, tick-borne disease foci are considered as **fixed foci** (i.e., of a permanent nature).

Such foci can of course be depleted of vertebrates or ticks. Food shortage, natural enemies, other infectious diseases and hunting can reduce the number of vertebrate maintenance hosts. Changes in

vegetation, tick die-off from disease, widespread use of pesticides, and other factors can deplete the tick population.

For stable maintenance of a focus, the areas of suitable tick microclimate must exceed the range of the vertebrate host or the suitable patches of microclimate must be sufficiently close together so that the range of vertebrates in one patch extends to another. Otherwise, ticks which attach to hosts in the focus will tend to drop off outside, where they will die. Thus, the focus will tend to be slowly depleted of tick population (Calhoun and Alford, 1955).

Role of Vertebrates and Ticks other than Maintenance Species

Other vertebrates may be temporary or incidental hosts of a tick-borne disease. These hosts although susceptible to infection do not contribute to the continued survival of the pathogen. Very often these hosts, in association with the vertebrate host, will show infection. However, in the absence of the vertebrate maintenance host, infection will not occur. Incidental vertebrate hosts may or may not exhibit disease symptoms. Some infections can be severe causing death. The incidental vertebrate hosts may be wild or domestic and may include man.

In the perpetuation of a focus or in the spread of infection outside the focus the incidental or temporary vertebrate host may have a significant role. For instance, the maintenance ticks may rely more on incidental hosts than maintenance vertebrate hosts for its own survival. In this case, incidental vertebrate hosts contribute to the perpetuation of that tick species primarily responsible for the maintenance of infection in another vertebrate species.

One of the most important ways an incidental host can contribute to the spread or acceleration of transmission is to act as an **amplifier**. This is particularly true of some domestic animals who by their presence greatly increase the tick population in an area and provide larger amounts of pathogen in circulation thus amplifying the total number of infected ticks per unit area.

Ticks also may be classified as either maintenance or incidental hosts of infection. However, another descriptive approach, the distinction between endemic and epidemic vectors, may more adequately explain the difference in tick vectors.

An endemic tick vector is a maintenance vector. It maintains the endemicity of infection among vertebrate hosts. The host specificity of this vector may be limited so that it feeds only on one or a few species of vertebrates. Among them may be the maintenance vertebrate host which usually does not show manifestation of disease. The epidemic vector is one which has a wider host range and feeds not only on the maintenance vertebrate host, but on other vertebrates who may show manifestation of disease. It is such vectors as these that transmit infections to man and domestic animals.

Factors Increasing the Probability of Man's Exposure to Tick-Borne Disease

Since an infected focus of ticks is relatively fixed and localized, large scale epidemics such as those associated with some mosquito-borne diseases, are not the usual order of events.

The incidence of human disease may differ between foci or increase due to alteration in some factor relating to the vector, reservoir or human susceptible.

An example of how incidence in humans can vary between foci is illustrated by a comparison of the occurrence of spotted fever in the western states with that in the eastern states. In the western states the tick transmitting spotted fever to man is *Dermacentor andersoni.* This tick feeds primarily on wild large animals, such as mountain goats, elk, and deer which would tend to remove ticks from areas around human habitation. In the eastern states the tick transmitting spotted fever to man is *Dermacentor variabilis,* a much more domesticated tick that feeds on such animals as dogs, cows and horses which tends to inject ticks into areas around human habitation. This difference in tick ecology seems to account for the higher human incidence reported for the east than for the west. For example, in the 5-year period 1959-1963, Virginia (the eastern state with highest incidence) reported 209 cases of spotted fever (1.0 cases/100,000/year) while Montana (the western state with highest incidence, reported only 16 cases (0.46/100,000/year).

The incidence of human disease associated with any one focus may increase due to a large scale invasion of the focus by man or an increase in the circulation and quantity of pathogens within the focus. Between March and December 1943 an epidemic of 50 cases of tularemia occurred among troops on Tennessee maneuvers. At least 32 of these cases were directly attributed to tick bites. This and other examples point up the importance of large scale invasions by man into a natural focus of tick-borne disease.

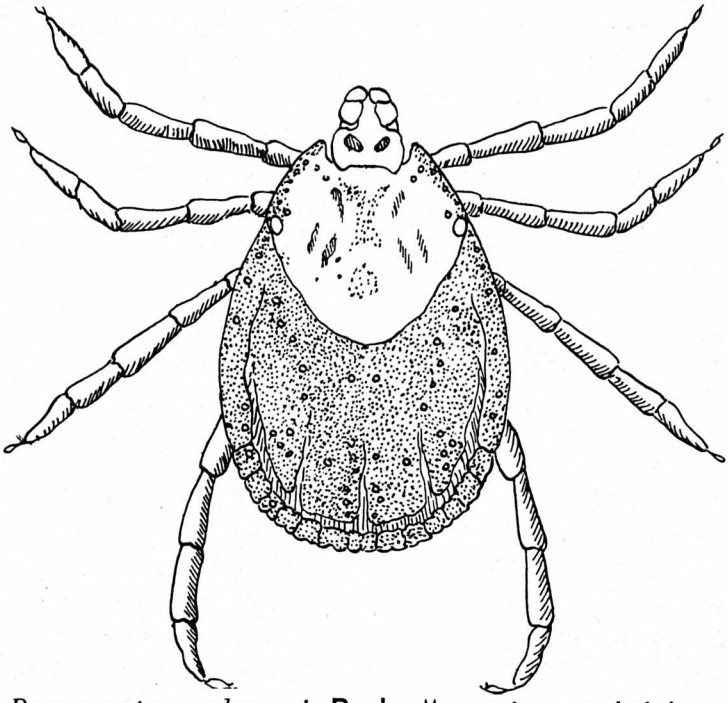
An increase in the circulation and quantity of pathogens within a focus is usually due to some change in the tick or reservoir host population. An increase in ticks can be brought about by a cyclic population peak in the small rodents serving as hosts for larval and nymphal stages. Such cyclic peaks may occur several seasons before an increase in human cases becomes noticeable. With such increases in ticks, or vertebrate hosts and the ensuing stepping up of pathogen circulation, factors relating to incidental transmission become more important. Ticks of wider host specificity become involved and infection more readily overflows into domestic animals as well as man.

For its spread in nature the disease depends upon the ticks, *Dermacentor andersoni, D. variabilis, D. occidentalis, D. parumapertus, Amblyomma americanum,* and *Haemaphysalis leporispalustris* which feed on rabbits and various rodents as well as other mammals. All are 3-host ticks which transmit tularemia from mammal to mammal and also from tick to tick via interstadial and transovarial transmission. The Rocky Mountain wood tick, *Dermacentor andersoni,* is found in the Rocky Mountain States and in southwestern Canada. Its life cycle requires 2-3 years for completion. Larvae and nymphs attack small mammals, adults large mammals including man. The American dog tick, *Dermacentor variabilis,* widely distributed east of the Rocky Mountains and on the Pacific coast, requires 4-12 months to complete its life cycle. Dogs are preferred hosts, but it readily feeds on other mammals. *Dermacentor parumapertus,* found in the western United States south of Oregon, Idaho, and Wyoming, completes its life cycle in about 12 months. Its preferred host is rabbits. The Pacific coast tick, *Dermacentor occidentalis*, found along the west coast, many complete its life cycle in less than 3 months. Preferred hosts include a wide variety of wild mammals and livestock.

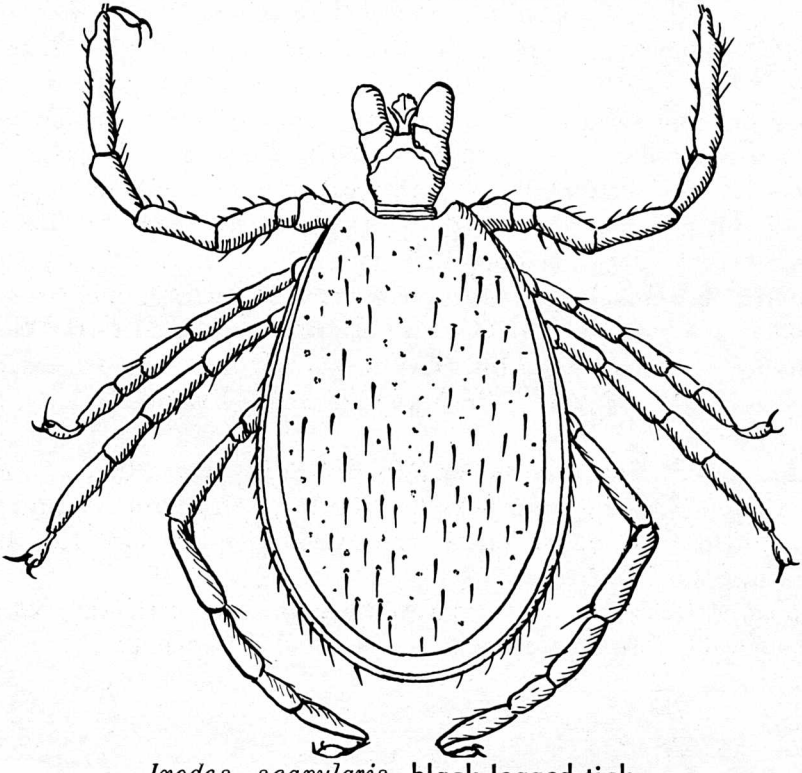
The lone star tick, *Amblyomma americanum,* found in the eastern United States and along the Gulf coast States to Texas, completes its life cycle in 2 years. Preferred hosts are livestock, dogs, deer, birds, and man.

The rabbit tick, *Haemaphysalis leporispalustris,* found in all of the United States except possibly Hawaii, completes its life cycle in as little as 75 days. Larvae and nymphs feed on birds, adults on rabbits, cats, and dogs.

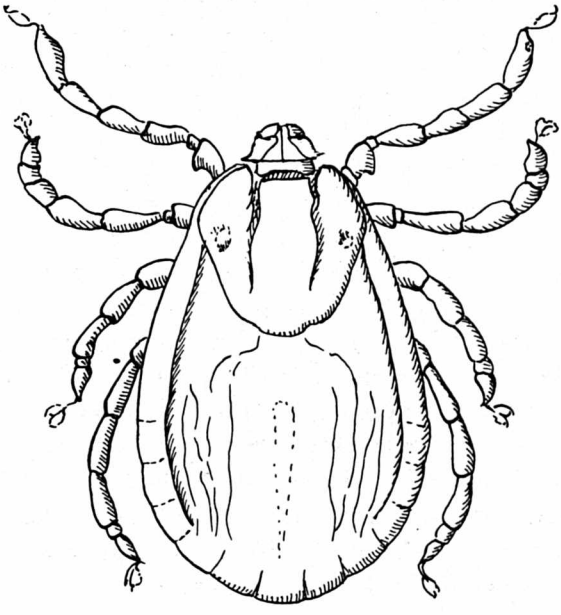
Ixodes ticks transmit tularemia between mammalian hosts but transovarial transmission is not considered to occur.



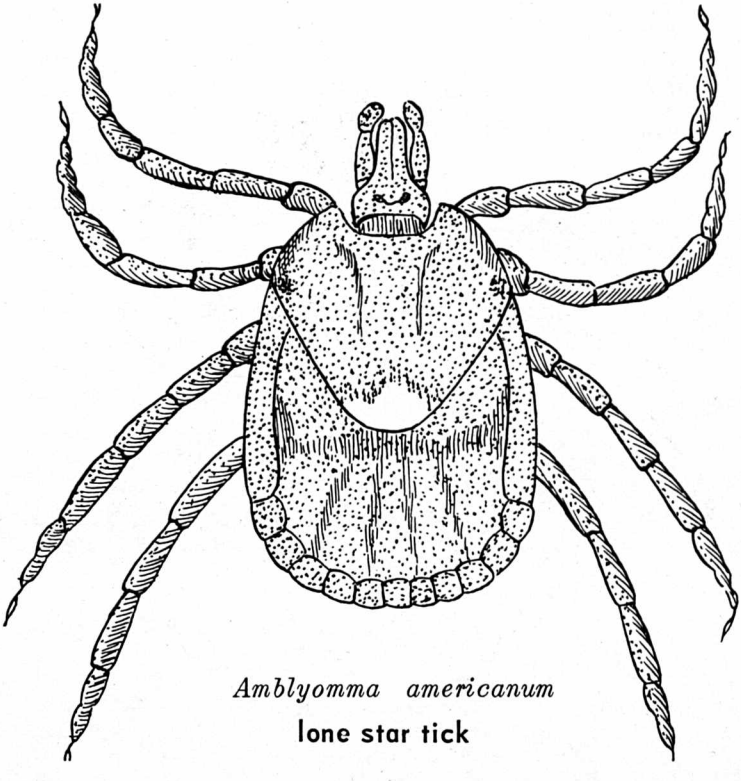
Dermacentor andersoni **Rocky Mountain wood tick**



Ixodes scapularis **black-legged tick**



Haemaphysalis leporispalustris
rabbit tick



Amblyomma americanum
lone star tick

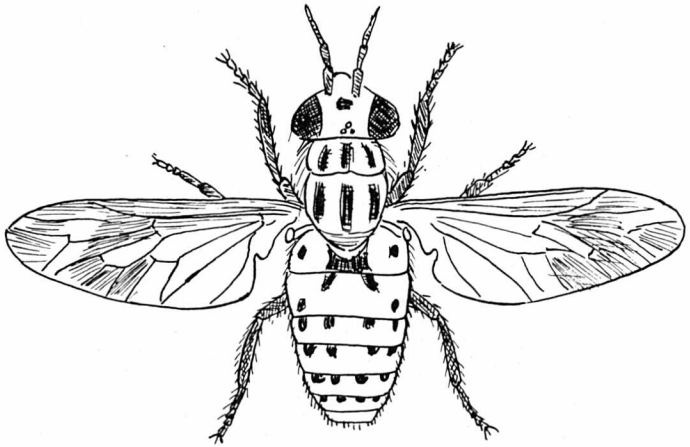
EPIDEMIOLOGY: DEER FLIES

Deer flies (Diptera: Tabanidae: *Chrysops*) are important vectors of tularemia in the United States, especially in Utah, while horse flies (Diptera: Tabanidae: *Tabanus*) are important vectors in Russia.

Deer flies are found in nearly all parts of the world and the females of all species suck blood. Many are vicious biters and can inflict painful injury to man. Male deer flies take plant juices or the body juices of other insects. Most species deposit their eggs near water, the larvae maturing in damp to wet soil and litter.

The effect of a deer fly's bite is an allergic response to the haemorrhagic saliva that is poured into the wound to prevent clotting of the blood during feeding. In some individuals the bites produce severe lesions, high fever, and even general disability.

Chrysops discalis is the only deer fly known to be a vector of tularemia. Transmission is considered to be mechanical. The individual fly becomes infected by biting a tularemic mammal and can transmit the disease for about five days.



Chrysops discalis
Deer Fly

EPIDEMIOLOGY: WATER

When tularemic mammal carcasses fall into streams or wells the water becomes contaminated with *Pasteurella tularensis* and can remain contaminated at least 33 days after the carcasses have been removed. Not only the water, but also the underlying mud may contain tularemia organisms.

Mammals, including man, drinking the water can become infected and localized epizootics may occur (Parker, *et al.*, 1951).

TULAREMIA SURVEYS: MAMMALS

A survey is required to determine which species of mammals in the area are transmitting diseases to humans and their numbers. The collection, preservation, and identification of specimens is necessary, specimens are captured alive for ectoparasite and blood disease studies. Population estimates can be obtained through the use of several techniques: sign surveys, mark and release trapping, and removal trapping.

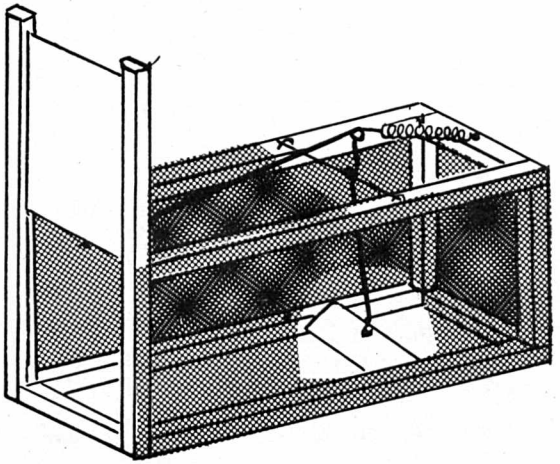
Collecting Specimens

Snap traps, live traps, or pitfalls can be used to collect specimens. Traps should be placed along fallen logs or around old stumps in woods or in runways in meadows and old fields for mice and voles. The heavy grass in meadows should be parted until active runways are found; fresh feces or bits of short green grass in the runways are evidence of use. The grass around the trap should be removed to avoid hindering the action of the trap. The snap traps should be set across the runway so that the treadle is in the runway. Bait will increase the catch, but is not necessary: almost any kind of seeds or rolled oats will do. The traps should be visited early in the morning before the sun is on them in the summer. Ordinary snap traps or live traps with inner dimensions of 2x2x8" are effective.

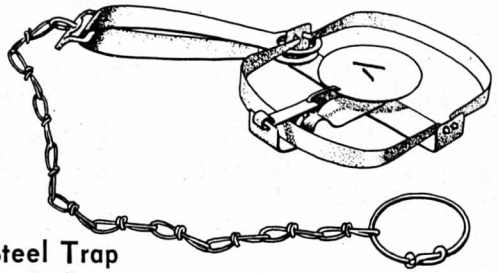
Simple and effective traps can be made from cans (about 6x8") placed in the ground with the rim just below the surface. The sides should be packed with earth, leaving the top exposed. Small holes should be punched in the bottom and nesting material (dry grass) added. These are effective for mice and voles.

Larger traps are needed for flying squirrels, chipmunks, and ground squirrels: rat traps or live traps with inner dimensions of at least 3x3x10" are ideal. Traps for flying squirrels should be set on branches or trunks of large trees; traps for chipmunks on or near old stumps, logs, or rubbish heads in or near forested areas; traps for ground squirrels near open burrow entrances. Any of these can be collected by shooting but traps give better specimens. Traps for flying squirrels should be visited early in the morning; those for others several times during the day.

Tree squirrels, marmots and woodchucks, rabbits and hares and carnivores are collected most easily with a shotgun with #6 shot or with a rifle. Although the use of large live traps will produce better specimens, these traps are too bulky to carry far afield.



Michigan trap



Steel Trap

Mammal identification is based on the following: external measurements; pelage color, pattern, and character; and skeletal characters, principally the skull. The standard measurements are:

total length; tail length; hind foot length; and sometimes ear length. Record these in millimeters before skinning the animals. Record catch location, sex, and date on the label of water-resistant cardboard with the measurements. For total length, place the animal on its back, straightened but not stretched, and measure the distance from the tip of its nose to the end of the tail vertebrae (do not include tip hairs on tail). For tail length, hang the body vertically, feet out, over the end of a ruler with the tail at right angles, measure the distance to the tip of the tail vertebrae. For hind foot length, measure the distance from the heel to the tip of the claw of the longest toe. For ear length, measure the distance from the lowest notch below the ear opening to tip of ear, excluding hair.

Sign Surveys

The relative abundance of small mammals in different years in the same area can be determined by counting signs in sample areas selected more or less at random. The signs will be fecal pellets, dens, runways, middens, or other fairly obvious signs of the presence of small mammals.

Fecal Pellet Counts

Fecal pellet counts have been used to estimate population indices for deer, rabbits, hares, mice, and shrews. Pellet quadrat counts, pellet spot counts, and dropping board counts are variations. The first two are most suited for estimating rabbit and hare populations; their pellets are large and easily seen. Since mouse pellets are small and hard to see in grass and leaves, the dropping board technique is well suited for estimating small mammal population indices.

For a quadrat count, count the pellets on a strip of measured length and width; use any convenient length, but a one-foot width is most convenient. Use permanent quadrats or select new quadrats at random each time.

For spot counts, use a wire hoop enclosing an area about one square foot. Place the hoop on the ground and count all pellets within it; proceed a predetermined distance and repeat the operation; continue this until enough counts are obtained for the population indices; proceed in a line or follow a grid pattern.

The dropping board technique is especially well adapted for determining small mammal population indices. Tan-colored plastic wall tiles (4½x4½″) or pieces of three-ply weather-proofed plywood (¼x4x4″) can be used as dropping boards in grassy or wooded areas. Dropping boards are set at designated spots without particular regard to the presence of runways or other signs; place them firmly

on the ground in a level position to avoid loss of droppings by tilting; disturb the vegetation as little as possible; mark the location of each board if necessary.

In servicing the boards, number each station, record the number and type of droppings at each, and clear the board for the next visit. Daily servicing is necessary in summer, and when small mammals are numerous. When mammal activity is low, 48 or even 72 hours may be needed to provide an adequate sample.

Mark and Release Trapping

Animals are captured alive, identified, marked in some manner, and released into the population. Once trapping starts, the trapped animals at each visit will consist in part of those previously handled and marked and in part of unmarked animals. A method for estimating population size after marking only part of the animals (Lincoln Index) has been in use for some time. Part of the animals in the population are marked; samples are next captured to observe the proportion marked in the entire population; an estimate of the total number is computed by dividing the total number marked in the population by the proportion marked in the samples, under the assumption that the samples will approximate the proportion marked throughout the entire population; the estimate will refer to the number present during the period of marking.

The turnover in any small mammal population is rapid; individuals are being replaced constantly, either by dispersal with replacement by unmarked individuals from adjacent areas or by natural mortality with replacement by younger unmarked individuals growing to adult stature. Lengthy separation of the preliminary marking period from the subsequent sampling period will result in an overestimation of the population size during the marking period. The shorter the period between marking and subsequent sampling, the less will be the effect of replacement within the population. The area must be trapped long enough, however, to insure that a representative sample of the population has been marked. A period of one week has been found satisfactory for the marking period, with a sampling period of one week following immediately.

A modification of the Lincoln Index bases a population estimate on the increase in the proportion marked in succeeding catches, as more animals become marked in the course of the survey. As marking progresses, the proportion of the population which is marked will increase. Marking an additional animal will cause the proportion marked to increase by a certain amount, and this increase is inversely proportional to the population number. After finding the average amount by which the marking of one further animal changes the

proportion of the population which is marked, it is easier to estimate the population.

The change in proportion marked in successive catches may be related to the number of animals, the marking of which produces the change, in the following manner: after a certain number (x) of the animals have been marked and released into the population (P) from which they were trapped, the proportion of the population now marked (y) may be written as—$y = x/P$ and the data plotted on a graph.

The best fitting, straight line passing through the origin may be fitted to the observed data by drawing it in by eye. The slope of the line is the reciprocal of the population number.

Removal Trapping

Where animals are removed as captured, a different approach is necessary. The number of animals captured during any trapping period is the product of two quantities, the probability of capture (p), and the number of animals present (P) at the beginning of the period. The probability of capture is assumed to be constant, describing the hazard of any animal in relation to capture in the traps during one period. The number of animals taken during any trapping period may be represented by the following equation:

$y = p(P - x)$ or, $y = pP - px$

P = original population

p = number captured first day

x = number previously captured and removed before beginning of period in question

When plotted, the slope is numerically equal to the probability of capture. After the probability is determined by fitting the catch data at hand, an estimate of P (the population) can be made, being the point at which the catch per period would become zero, or by computing the quantity using the equation.

Sample Area

Regardless of the method used to determine a population index, the size of the area to be sampled must be considered. The area should be from 10 to 20 times the expected size of the home range of the species involved. A plot of less than five acres, however, would be too small for accurate determination of population densities of most small mammals, while a plot larger than fifteen acres would be too large for one individual to handle.

Traps

Traps are needed in either the mark-and-release or removal-survey method. Many have been designed for small mammals. Some are set off by a treadle or false bottom, some by the release of a wire holding the door open, and some by the animal as it pushes the

door open. The doors may be closed by a spring mechanism or by gravity. A trap should be simple yet sturdy, easy to construct, light to transport, inexpensive to build, and it must protect the animals captured from the elements. A number of commercial traps are available: they are expensive in quantity; frequently they are too heavy; and they are seldom designed for special needs.

The trap to be used should be selected with care depending upon the circumstances as well as the animals sought. A single catch trap will probably be preferred. Traps with an outside mechanism will be impeded if set in deep grass or underbrush. Wire traps are far better than those of wood or sheet metal in hot climates, especially when trapping diurnal species, even so, shade over the trap should be provided. A wad of dry grass should be deposited in the trap for nesting material, expecially for nocturnal forms, or heavy mortality can be expected during severe weather. Wooden traps provide better insulation against heat or cold, but are bulky to transport; they are also frequently damaged by gnawing, either from the outside or within. In all but the sturdiest traps, there will be times when the trap is sprung by red squirrels, porcupines, rabbits, or other animals jarring or overturning them. Human scent on the traps does not seem to detract from their effectiveness.

Baits

The bait to be used will depend on the species sought. Rolled oats, barley, or corn meal have a wide appeal, but form a soggy mass when wet. A mixture of peanut butter and rolled oats has a wide appeal for small mammals and has been used successfully. Whole grains, such as rice, wheat, hemp, sunflower seeds, or corn, may jam the treadle in traps with a false bottom. Ear corn has been used successfully in live catch traps.

Marking

The method of marking should be chosen with a view to the species of mammal concerned, as well as the object to be attained. In general, the marking should be inexpensive, quickly and easily applied, humane, conspicuous, and permanent. Fingerling tags have been used successfully on squirrels, rabbits, chipmunks, mice, and voles. Pyralin markers (a light, durable, and flexible plastic) in nine colors have been attached to rabbit ears with staples, enabling ready identification of individuals up to 100 yards with field glasses.

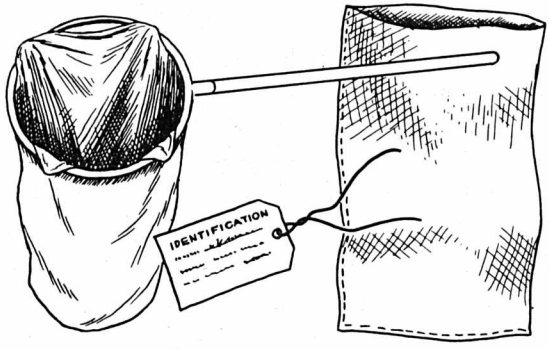
Various types of mutilations have been used for marking mammals. They are easily and painlessly applied, relatively permanent, and, when used in proper combinations, can mark individuals serially into the thousands. On the other hand, ear marks are sometimes obliterated by tearing; excised toes might conceivably hamper move-

ments; and either of these markings may be easily overlooked by one not on the alert for them. Ground squirrels, chipmunks, and mice have been marked by various combinations of holes punched in the ears, excised toes, and docking the tail. Ears of small mammals can be easily punched with a metal poultry punch, or a No. 1 harness punch; toes are simply excised, near the base, with sharp scissors.

Branding techniques have been applied to various mammals. Ground squirrels have been marked by singeing the hair tips, thus exposing the dark base of the pelage; these markings last only until the next molt. Various dyes and paints have been used for marking. The result should be permanent and conspicuous, and should have no toxic or hampering effect on the individual. In nearly all cases, the mark lasts only until the next molt. Ground squirrels have been marked with picric acid crystals dissolved in five percent formalin. A successful dye has been used on mice, squirrels, woodchucks, and rabbits: Nyanzol A (20 grams in 1 liter water-hydrogen peroxide 2:1) produced a uniform dark purplish-black coloring which lasted until the next molt.

Tularemia Detection In Mammals

Captured mammals are placed in cloth bags, each in a separate bag. A special metal hoop is used to hold the bag while placing an animal in it. A tag is attached to each bag listing date, place, and name of collector. In large-scale surveys, each animal is given a reference number. Data should remain with the mammal throughout the examination. Do not allow animals to stay in bags over two or three hours as they may chew their way out.

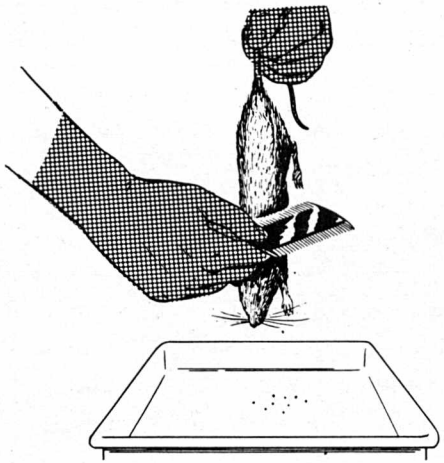


Cloth Bag

Anesthetize live mammals by placing them in a jar containing approximately two inches of cotton and a small amount of ether. Leave in bag so ectoparasites do not become mixed. When the animals are anesthetized, start examination. Do not anesthetize more animals than the individuals who are doing the testing can handle immediately.

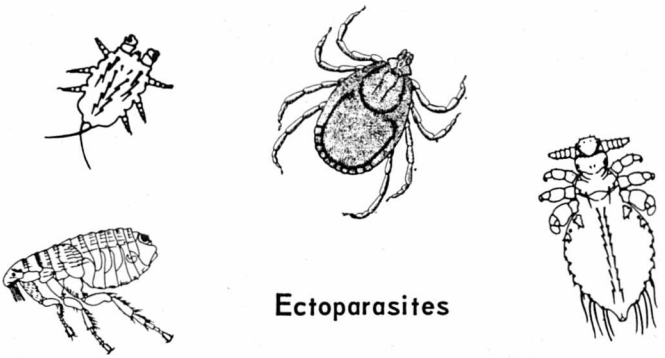
Instruments (vials, needles, syringes, combs, cotton, forceps, pipettes, pinning tray, gloves) utilized in drawing blood and urine, and in taking tissue samples, should be sterilized. Always wear rubber gloves while making the tests. A pinning tray with wax in the bottom (14″ x 19″) is used for holding animals in place while drawing blood.

Remove ectoparasites with a fine-toothed comb while holding animal over a white pan. Remove sticktight fleas and ticks with forceps. Ectoparasites may also be removed by swirling mammal in a water-detergent mixture for several minutes, and filtering off ectoparasites on filter paper. In either case, the cloth bag should be turned inside out and shaken to remove additional ectoparasites. Place ectoparasites to be identified in 70% alcohol. Store ectoparasites to be tested for disease organisms in 2 percent saline solution.



Combing

Preliminary identification of fleas, lice, mites and ticks is accomplished with the dissecting microscope. Record is kept of each collection: date, location, mammal number, and trapper's name. Determinations are checked later using a compound microscope. Specimens should be stored for later reference. The ectoparasite index (average number of specific ectoparasites per mammal) is of value in predicting incipient epidemics; i.e., the higher the index, the greater the probability of a human disease outbreak.



Ectoparasites

Draw blood by inserting a size 20 hypodermic needle into heart and gradually pulling back plunger of syringe (10 cc size). Centrifuge blood at 1800-2000 rpm for 20 minutes, pour serum only into vial, label, and submit to laboratory. If blood smears are to be made they should be made from noncentrifuged blood immediately after blood is taken.

Tests run on serum include: (1) **Fluorescent Antibody Test,** a specific reaction between fluorescein-labelled antibodies and specific surface antigens of *Pasteurella tularensis;* (2) **Complement Fixation (CF),** a specific reaction between serum antibodies and antigens from pathogenic organisms; (3) **Agglutination,** observation of clumping of specific organisms by serum antibodies on suspensions of homologous disease organisms; (4) **Direct Culture,** an attempt to isolate disease organisms on nutritive media; and (5) **Inoculation,** an attempt to develop the disease in other animals.

Dissection following blood and ectoparasite collection allows for observation of internal organs and selection of tissue for pathological and microbiological examination. Gross observation can give presumptive evidence of tularemia.

Shipment of specimens involves careful packing and labelling. Always include a packing list indicating what tests are desired, and the individual to whom results are to be sent. Mark package **Fragile** and **Laboratory samples.** Perishable items are shipped by fastest means in wet ice. This should also be indicated on the outside of the package: **Perishable, Rush.**

Precautions to be observed during the examination of mammals for disease include: (1) wearing gloves; (2) no smoking in rooms where ether is being used; (3) dusting dead animals with 10% DDT to kill any ectoparasites missed in combing and swirling; (4) seeing a physician immediately in event of bite or illness; (5) washing hands with alcohol and soap and water after removing gloves; and (6) disposing of carcasses by incineration or burial in a sanitary landfill as soon after examination as possible.

TULAREMIA SURVEYS: TICKS AND DEER FLIES

Ticks suspected of having tularemia are collected from host animals or with a drag (3x4½-foot white flannel cloth attached to 3-foot pole with rope at ends to allow for dragging; pull drag 50 feet across ground, then turn over and remove ticks with forceps).

Whenever possible ticks should be transported alive in moisturized tubes in an insulated box cooled with ice or freeze cans.

If live transportation is not possible, transport on dry ice. This may preclude culture of *Pasteurella tularensis* but will not interfere with the fluorescent antibody technique.

Shipment of live specimens by air may result in first freezing (at high altitudes in the non-airconditioned cargo compartment) then heating. Therefore, either insulative protection or dry ice shipment should be employed.

Deer flies are collected by parking an empty car in the sun with the windows open. When a number of flies have entered, close windows and collect flies with an aspirator.

Transporting of deer flies alive is difficult but is highly desirable. Dry ice shipment is second choice. Follow instructions given for ticks.

TULAREMIA SURVEYS: WATER

Water suspected of being contaminated with *Pasteurella tularensis* is collected in sterile 200 ml. bottles. Each of ten guinea pigs are injected intraperitoneally with 10 ml. of the water. They are observed for 21 days and evaluated as described under the section on **Clinical: Diagnosis.** Result cannot be considered positive until bacteriological isolation of *Pasteurella tularensis* or a positive test with fluorescent antibody has been accomplished.

Mud suspected of being contaminated with *Pasteurella tularensis* is collected in sterile 500 ml. bottles. Each sample consists of three tablespoonfuls of top mud plus 300 ml. of tap water. The mixture is shaken thoroughly and the suspended material allowed to settle. The supernatant is then injected into guinea pigs as described for water above.

If interval between collecting and testing is more than four hours, samples should be transported in an insulated box with ice or freeze cans in it.

Often mud samples are positive when overlying water is negative and vice versa. Therefore, both types of samples should be taken. Precise locations of sampling points should be recorded.

DISTRIBUTION AND INCIDENCE

Tularemia is known to occur in the United States, Canada, Mexico, Norway, Sweden, Germany, Austria, Czechoslovakia, Turkey, Russia and Japan.

In recent years (1959-mid-1964) it has been reported from 43 of the United States, being unreported in Maine, New Hampshire, Vermont, Connecticut, Rhode Island, North Dakota and Hawaii.

Seasonal peaks of tularemia are associated with hunting and outdoor recreation periods and with high deer fly and tick populations or infection rates.

In the western United States infection is more common in the summer, in the eastern States in the winter.

In the West,ticks are particularly dangerous from March to August, deer flies from June to September, jack rabbits from April to October.

In the East most human infections are contracted from November to January, the months when cottontails are hunted.

The reported incidence of tularemia, 1959-1963, was 1,819 cases (364/year). In 1963, 277 cases were reported. This reduction in case rate resulted from lowered incidence in six western and thirteen eastern states.

In the 1959-1962 period, Oregon, Nevada, Utah, Nebraska, Kansas and Texas reported 246 cases (62/year), but only 29 in 1963.

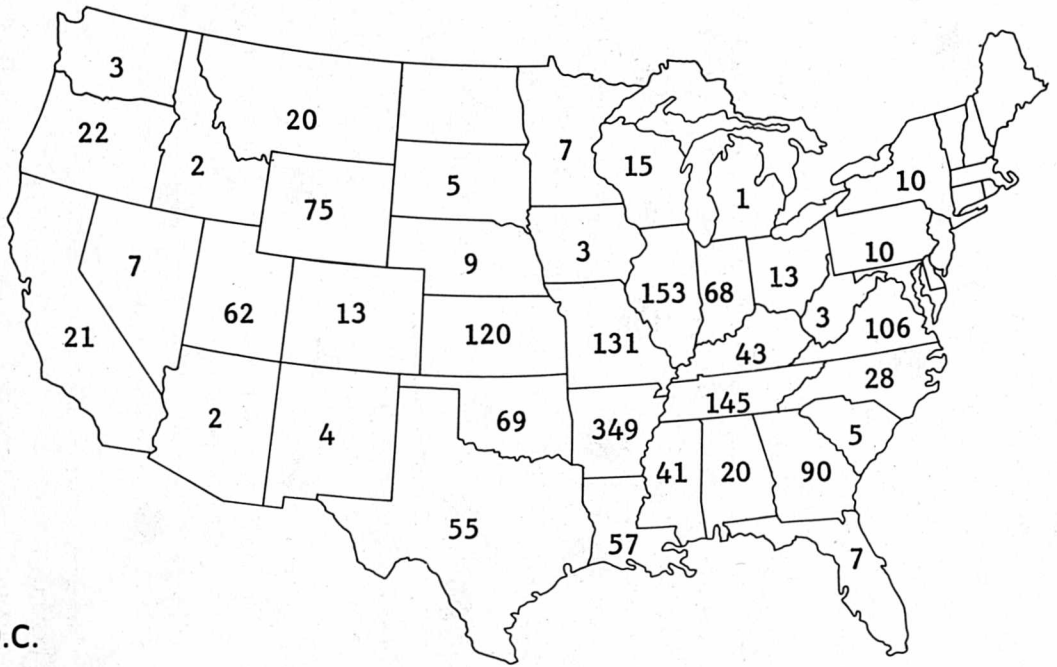
In the 1959-1962 period, Wisconsin, Illinois, Indiana, Ohio, Pennsylvania, New York, Maryland, Virginia, Kentucky, Tennessee, North Carolina, Alabama and Mississippi reported 620 cases (155/year), but only 46 in 1963.

At the same time five western and four eastern states showed significant increases in reported cases.

In the 1959-1962 period, California, Montana, Colorado, South Dakota, and Oklahoma reported 94 cases (24/year), compared with 34 in 1963.

In the 1959-1962 period, Arkansas, South Carolina, Georgia and Florida reported 344 cases (86/year), compared with 107 in 1963. Arkansas carried the larger part of this higher incidence with 267 cases (67/year) in the 1959-1962 period, compared to 82 cases in 1963, a 22.4% increase.

REPORTED CASES OF TULAREMIA 1959-1963

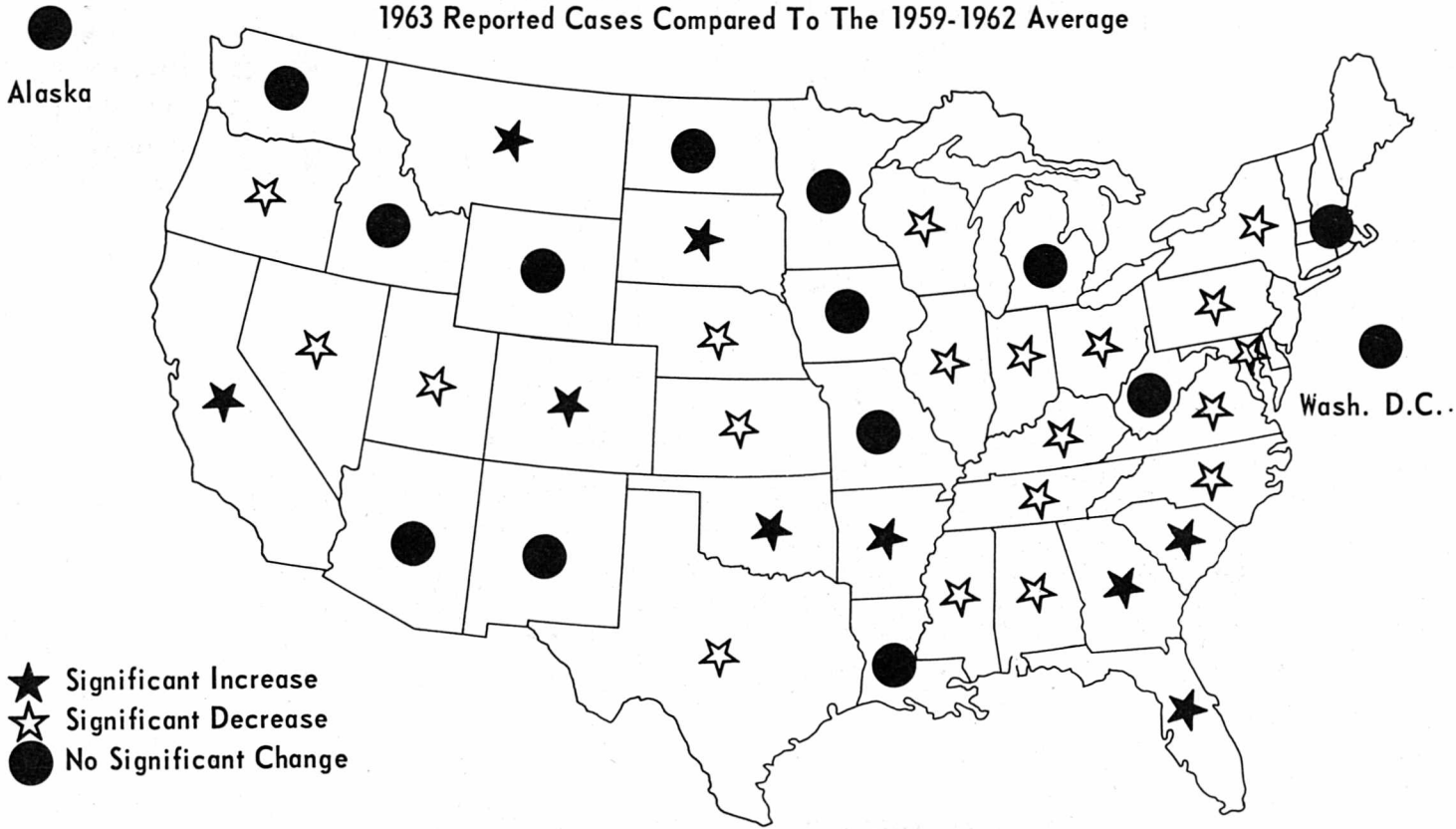


3 Alaska
1 Delaware
1 Washington D.C.
14 Maryland
4 Massachusetts
2 New Jersey

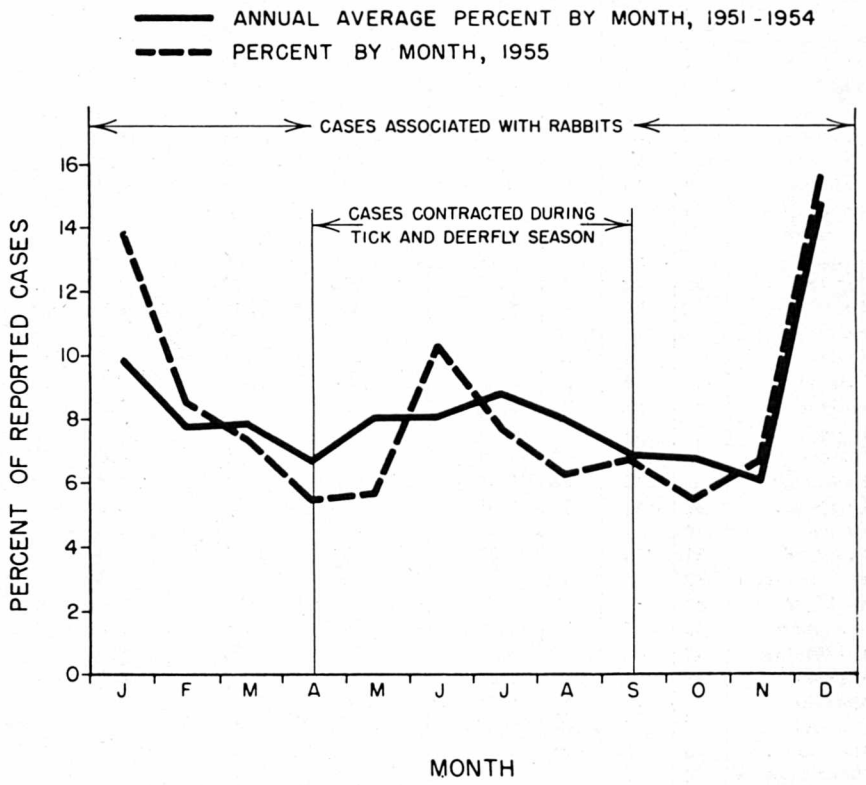
TOTAL CASES IN UNITED STATES 1,819

TULAREMIA

1963 Reported Cases Compared To The 1959-1962 Average



SEASONAL DISTRIBUTION
REPORTED CASES OF TULAREMIA, U.S.



Tularemia Reported in the United States

1945 – 900	1959 – 459
1947 – 1401	1960 – 390
1950 – 927	1961 – 365
1955 – 584	1962 – 328
1957 – 601	1963 – 277

TULAREMIA	Estimated 1962 population in 100,000s	Cases Reported 1959 - 1963	Cases Reported 1963	Cases/100,000/year 1959 - 1963	Cases/100,000/year 1963	Percent of U.S. Cases 1959 - 1963	Percent of U.S. Cases 1963
Alabama	34	20	1	0.12	.029	1.10	0.36
Alaska	2	3	2	0.30	1.0	0.16	0.72
Arizona	15	2	–	0.03	–	0.11	–
Arkansas	18	349	82	3.88	4.6	19.18	29.60
California	170	21	5	0.3	.029	1.15	1.84
Colorado	19	13	4	0.14	.21	0.71	1.44
Connecticut	26	–	–	–	–	–	–
Delaware	5	1	–	.04	–	–	–
D.C.	8	1	1	.03	0.13	.06	0.36
Florida	55	7	4	.03	.073	.38	1.44
Georgia	41	90	19	0.44	.46	4.95	6.86
Hawaii	7	–	–	–	–	–	–
Idaho	7	2	–	.06	–	0.11	–
Illinois	101	153	10	0.30	.099	8.41	3.61
Indiana	47	68	3	0.29	.06	3.74	1.08
Iowa	28	3	–	.02	–	0.16	–
Kansas	22	120	19	1.09	.86	6.60	6.86
Kentucky	31	43	2	0.28	.06	2.36	0.72
Louisiana	33	57	12	0.35	.36	3.13	4.33
Maine	10	–	–	–	–	–	–
Maryland	31	14	4	.09	.13	0.77	1.44
Massachusetts	52	4	1	.02	.02	0.22	0.36
Michigan	80	1	–	.003	–	.06	. –
Minnesota	35	7	2	.04	.06	.38	0.72
Mississippi	22	41	2	0.37	.06	2.25	0.72
Missouri	43	131	28	0.61	.65	7.20	10.11
Montana	7	20	6	0.57	.86	1.10	2.17
Nebraska	15	9	–	0.12	–	.49	–
Nevada	3	7	–	0.47	–	.38	–
New Hampshire	6	–	–	–	–	–	–
New Jersey	62	2	–	.01	–	0.11	–
New Mexico	10	4	–	.08	–	0.22	–
New York	174	10	1	.02	.006	.55	0.36
North Carolina	47	28	2	0.12	.04	1.54	0.72
North Dakota	6	–	–	–	–	–	–
Ohio	101	13	2	0.03	.020	0.71	0.72
Oklahoma	24	69	16	0.58	.067	3.79	5.78
Oregon	19	22	–	0.23	–	1.21	–
Pennsylvania	114	10	1	0.02	.009	.55	0.36
Puerto Rico	25	–	–	–	–	–	–
Rhode Island	9	–	–	–	–	–	–
South Carolina	24	5	2	.041	.08	0.27	0.72
South Dakota	7	5	3	0.14	.43	0.27	1.08
Tennessee	36	145	9	0.81	.25	7.97	3.25
Texas	101	55	7	0.11	.07	3.02	2.53
Utah	10	62	3	1.24	.30	3.41	1.08
Vermont	4	–	–	–	–	–	–
Virginia	42	106	7	0.50	.17	5.83	2.53
Washington	30	3	–	0.02	–	.16	–
West Virginia	18	3	–	.03	–	.16	–
Wisconsin	41	15	2	.07	.05	.82	0.72
Wyoming	4	75	15	3.75	3.75	4.12	5.42
TOTAL	1881	1819	277	0.19	0.15	99.87	100.01

PREVENTION: GENERAL

Tularemia, ecologically entrenched in the United States, 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 practical things which can be done to minimize the tularemia hazard now and in the future:

1. We can minimize human contact with infected rabbits, ticks, deer flies, and other vector animals, particularly during peak tularemia times, via thoughtful scheduling of hunting seasons, recreational activities, jamborees, encampments, and outdoor conventions.

2. We can limit human contact with infected vectors by environmental and pesticidal control at sites regularly visited by large numbers of people.

3. We can reduce human tularemia by promoting the prompt and proper tick removal from humans by physicians, nurses, pharmacists, camp and scout leaders, persons trained in first aid, teachers, and anyone else who might regularly engage in this activity.

4. We can reduce human incidence of tularemia by fostering proper deticking of dogs and other domestic animals by veterinarians, stockmen, and pet owners.

5. We can foster extreme care in laboratories and clinics where tularemia organisms are being handled or where they might be encountered unexpectedly.

6. We can post warnings in heavily tularemic areas regarding avoidance of contacts with mammals, ticks, deer flies and contaminated water.

7. We can plan what we will do when tularemia jumps out of control as a result of natural disaster, military aggression, economic aberrations, or biological shift. We can also plan what we would do if tularemia should be used as a biological warfare agent by an aggressor. Emergency vector control is at its best when preplanned.

8. We can continue to investigate the etiology, epidemiology and status of tularemia in the United States, interpolate knowledge developed in other countries, and thereby, increase our knowledge of and competence in tularemia control.

9. We can mount a coordinated disease control program, utilizing any and every economically feasible technique, evaluating each technique insofar as possible by the effect it has on tularemia incidence, and continually watching for new effective techniques which can be added to our arsenal.

10. We can educate all citizens regarding the tularemia hazard and how it can be avoided. This training should be a part of the education of every schoolchild as long as we stand in the shadow of tularemia.

There are also some things which we cannot do with regard to the tularemia problem:

1. We cannot relax the empirical techniques of environmental sanitation, effective clinical treatment, immunization of hazard groups, and vector abatement. While these techniques probably are unable, within economic limits, to further lower tularemia incidence, they are among the major forces maintaining the present endemic plateau. If these controls are relaxed, tularemia incidence will almost surely rise.

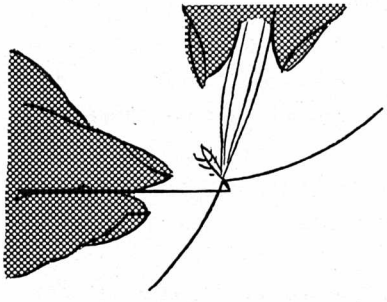
2. We cannot depend upon empirical control to hold tularemia indefinitely at or below the present endemic plateau. Economic aberrations, natural disasters, or military aggression can destroy these defenses overnight. Biological variability can breach these defenses without warning. For example – bionomic shifts to avoid pressures generated by empirical control can produce (a) epidemiologic patterns which avoid the absolutism of environmental sanitation, (b) pathogens resistant to available therapeutic agents or with increased virulence, (c) mutant pathogens refractory to available vaccines, and (d) vectors resistant to pesticides or with increased transmission efficiency.

3. We cannot turn aside from this disease with the thought that its low incidence and firm enzootic entrenchment make further effort futile. Without doubt there are economically feasible control techniques to which the tularemia plateau would yield. It simply remains for us to find and employ these techniques.

Some Methods of Tularemia Prevention

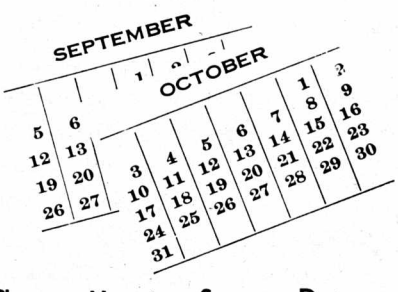
Avoid Contact with Rabbits

Avoid Contact with Ticks

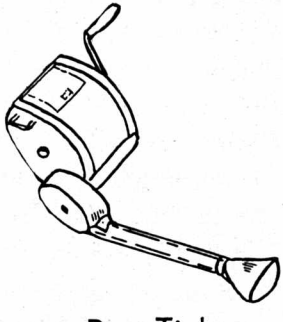


Remove Ticks Properly

Avoid Impure Water

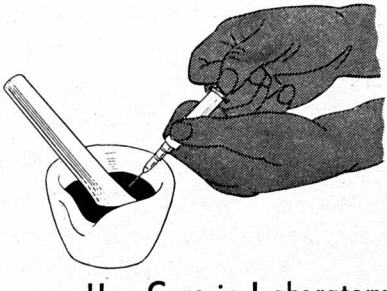


Change Hunting Season Dates



Dust Ticks

Cook Wild Meat Thoroughly



Use Care in Laboratory

PREVENTION: MAMMAL ABATEMENT

Mammal populations are limited by (1) Food; (2) Harborage; (3) Disease; (4) Predation, especially by man; and (5) Competition for benefits of the environment.

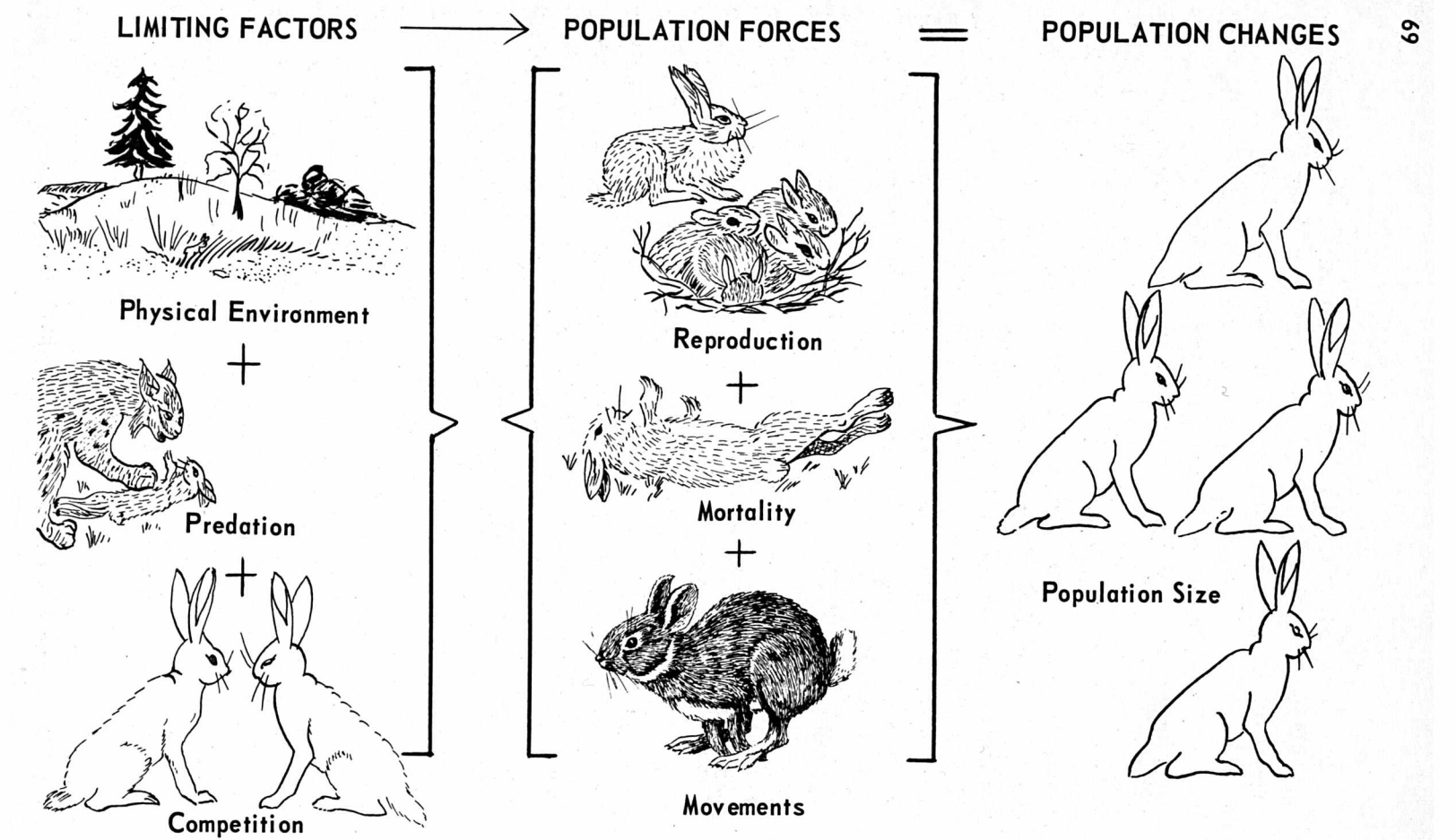
Mammal populations are modified by (1) Reproduction; (2) Mortality; and (3) Migration. More mammals are born than can survive. Since the numbers of mammals an area can support are limited by the environment, excess animals must migrate or die. Mammal "blooms" (population upsurges) occur when one limiting factor or more becomes ineffective.

Primary steps in control are: **Survey** – to determine type and degree of infestation. **Ectoparasite Control** – to prevent disease transmission by fleas, mites, ticks, and kissing bugs which might bite man when their hosts are killed. **Trapping and Poisoning** – to reduce populations temporarily until more permanent measures are in force. **Repelling** – to keep mammals from harming valuable items. **Field Sanitation** – to reduce food and harborage. **Exclusion** – to prevent access to control areas.

Control of ectoparasites should precede any attempt to control large populations of mammals. Failure to do this may result in transfer of ectoparasites to man and an increased probability of disease transmission. Even in areas where disease has not been a problem, cases may occur after mammal control without ectoparasite control. For flea, tick, and kissing bug control, dust burrows with 10% DDT. For mite control use 4% malathion dust. Insecticide should also be placed in bait boxes. Individuals should stay away from areas where dead or dying rodents are to be found.

Trapping success depends upon precise knowledge of the species involved plus clear understanding of limitations of the trapping method. Even intense trapping will reduce populations only temporarily. Populations will soon return to their former levels.

Buildings in rabbit or field-rodent infested areas are "rodent-stopped" to prevent intimate contact between these animals and man, and stored-product damage. Methods of domestic rat-proofing are used except that maximum permissible opening must be adjusted to prevent entry of young field rodents. Rodent-proof fences are erected to limit migration. The fence is constructed so rodents cannot pass through, climb over, or jump over. An L-shaped subterranean base prevents burrowing under. Ends of the fence line are


LIMITING FACTORS
POPULATION FORCES
POPULATION CHANGES
Physical Environment
+
Predation
+
Competition
Reproduction
+
Mortality
+
Movements
Population Size

angled 45° to discourage bypassing. One-way exits are installed to allow rodents to leave but not enter the protected area. Effectiveness of fences is limited.

Reduction of field-rodent and rabbit populations on farms is of great importance to decrease economic losses and protect the health of farm workers. Continuous clean cultivation minimizes populations at first, but destroys soil humus, hastens erosion, encourages drought damage and leads to larger populations eventually. Therefore, cover is kept low through repeated mowing or with selective weed-killers. Fields and fence rows are kept clear of rubbish. Marshy areas are drained or filled. Following harvest, fields are left as free of waste food as possible. Disease-weakened crops are more subject to attack than healthy crops.

Poisons give temporary control, but populations shortly rebuild. Burrow fumigation with cyanide or other fumigant gives rapid temporary relief, and when sufficiently intense clears limited areas. Single-shot poisons (zinc phosphide, arsenic, thallium, 1080), though dangerous will give partial control over limited areas. Proper use of anticoagulants (warfarin, fumarin, pival, pmp, diaphacin; 1 part 0.5% concentrate/19 parts cornmeal or other bait exposed at least 14 days) will keep populations down, but is expensive over large areas and/or long times. Spraying 20% endrin gives good control but is extremely dangerous to man and wildlife. Repellents (cefro, DR-1669, TMTD, ZAC, phenylnitropropene, n-butylphthalimide) keep rabbits and rodents from limited areas or specific items.

Since human-field rodent contact usually involves invasion of the rodent habitat by man, education is a most effective method of disease control. Individuals are instructed to: (1) recognize hazards presented by field mammals; (2) avoid handling, feeding, or hunting them; (3) avoid areas exhibiting dead or dying animals; (4) keep from homes, farms, and campsites; (5) report animal bite or illness contracted after field-mammal contact to a physician at once.

Personnel engaged in survey and control are instructed to avoid undue contact with the animals or their ectoparasites. Immunizations are given to such personnel when indicated.

PREVENTION: TICK ABATEMENT

Ticks suck blood and transmit spotted fever, tularemia, relapsing fevers, 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.

Fill cracks and crevices where soft ticks hide. Keep rodents and other mammals out of buildings. In tick-infested areas wear impregnated protective clothing; check each 2 hours for attached ticks; clear vegetation from paths and yards.

Impregnate clothing (25% benzyl benzoate emulsion; soak clothing; then air dry). Use diethyl-toluamide repellent. Residual spray (5% DDT, 3% chlorodane, 0.5% dieldrin, or 0.5% diazinon at 1 gal./1000 sq. ft.) or dust (10% DDT, 4% malathion at 20 lb./acre) infested buildings and areas. Treat 4-foot swaths along walkways. Dust pets (3% malathion, 1% lindane, or 1% rotenone). Do not use lindane on cats.

Tick abatement is economically feasible and bionomically practical only on limited areas or along human pathways (Pratt and Littig, 1962).

PREVENTION: LABORATORY PRECAUTIONS

Only experienced workers should attempt to deal with *Pasteurella tularensis* in the laboratory. Work should be done in a negative pressure safety cabinet wearing gloves, mask, and autoclavable gown.

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. of Utah, Salt Lake City, 67 pp.

Arthur, D. R. 1962. Ticks and Disease. R. W. Peterson, New York, 445 pp.

Burroughs, A. L., Holdenreid, R., Longanecker, D. S., and Meyer, K. F. 1945. A field study of latent tularemia in rodents with a list of all known naturally infected vertebrates. J. Infect. Dis., **76**:115-119.

Calhoun, E. L. 1954. Natural occurrence of tularemia in the lone star tick, *Amblyomma americanum* (Linn.), and in dogs in Arkansas. Amer. J. Trop. Med. Hyg., **3**(3):360-366.

Calhoun, E. L., and Alford, H. I., Jr. 1955. Incidence of tularemia and Rocky Mountain spotted fever among common ticks in Arkansas. Amer. J. Trop. Med. Hyg., **4**:310-317.

Green, T. W., and Eigelsbach, H. T. 1950. Immunity in tularemia. Report of two cases of proved reinfection. Arch. Intern. Med., **85**:777-782.

Herms, W. B. 1953. Medical entomology. The Macmillan Co., New York, 643 pp.

Jellison, W. L., and Kohls, G. M. 1955. Tularemia in sheep and in sheep industry workers in western United States. Public Health Monog. No. 28, iv + 17 pp.

Jellison, W. L., Owen, C. R., Bell, J. F., and Kohls, G. M. 1960. Tularemia and animal populations: ecology and epizootiology. Wildlife Dis., No. 17, 23 pp.

Jellison, W. L., and Parker, R. R. 1945. Rodents, rabbits and tularemia in North America: some zoological and epidemiological considerations. Amer. J. Trop. Med., **25**:349-362.

Kartman, L., Prince, F. J., and Quan, S. F. 1959. The Oregon meadow mouse irruption of 1957-58: epizootiological aspects. Fed. Coop. Serv. Oregon State College, pp. 43-54.

Maxcy, K. F. 1956. Rosenau Preventive Medicine and Public Health. Appleton-Century-Crofts, Inc., New York, xv + 1465 pp.

McDowell, J. W. 1964. Epidemiological considerations in tick-borne disease. Communicable Dis. Center, US PHS, 14 pp.

Parker, R. R., Steinhaus, F. A., Kohls, G. M., and Jellison, W. L. 1951. Contamination of natural waters and mud with *Pasteurella tularensis* and tularemia in beavers and muskrats in the northwestern United States. Natl. Inst. Health, Bull. 193, 89 pp.

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

Saslaw, S., Eigelsbach, H. T., Wilson, H. E., Prior, J. A. and Carhart, S. 1961. Tularemia vaccine study. Arch. Intern. Med., **107**:689-714.

Simmons, S. A., Stevens, I. M., and Reeves, W. C. 1953. Some epidemiological observations on tularemia in California. Amer. J. Trop. Med. Hyg., **2**:483-494.

Van .Metre, T. E., Jr., and Kadull, P. J. 1959. Laboratory-acquired tularemia in vaccinated individuals: A report of 62 cases. Ann. Intern. Med., **50**:621-632.

Washburn, A. M. and Tuohy, J. H. 1949. The changing picture of tularemia transmission in Arkansas. A Study of 704 Case Histories. Southern Med. J., **42**:60-62.

Williams, R. C. 1951. The United States Public Health Service: 1798-1950. Comm. Officers Assoc., US PHS, Washington, D. C., 890 pp.