of actinomycosis of the udder in sows. The infection is now thought to enter from the mouths of suckling pigs through wounds made by their teeth.

Abrasions or lacerations in the oral cavity in cattle are believed to be the primary portal of entry for infections of actinomycosis and actinobacillosis. Dry, harsh, rough feeds may cause injuries to the mouth. Particles of hay or grain, especially the barbed awns of barley and bearded grasses, often are found in the oral lesions and sometimes are covered with a growth of either *A. bovis* or *A. lignieresii*. In such cases, the vegetable particles probably acted as a foreign body about which the organisms grew. Neither of the two microorganisms has ever been reported on such material except when it has been incorporated into abscesses in the living animal.

Teething may be the explanation for the more frequent occurrence of both infections in young cattle. Lacerations, swelling of the gums, and the trapping and decay of foodstuffs in the oral cavity accompany the eruption of the permanent teeth during the first 3 years of life of the domestic bovine animal.

PREVENTIVE MEASURES that can be adopted to reduce actinomycosis and actinobacillosis infections have been limited to the application of basic concepts of animal sanitation. The only proved transfer of infection from one animal to another is by the inoculation of diseased tissues or cultures.

Animals of all species affected with either disease should not be permitted to remain in pastures or feed lots with healthy cattle. This will prevent pus from open lesions from contaminating food, water, bedding, or cuts and abrasions in noninfected animals.

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**Anaplasmosis of Cattle**

JOHN C. LOTZE, DANIEL W. GATES, AND T. O. ROBY

ANAPLASMOSIS, sometimes called gall sickness, is a disease of cattle that is marked by anemia and fever and microscopic parasites in the red blood cells.

It is infectious and transmissible. It occurs the world over and is especially troublesome in the warmer regions.

The causative agent, *Anaplasma marginale*, apparently belongs to the Protozoa, a group of minute, one-celled animals that includes such organisms as the causative agents of coccidiosis and malaria.

The first account of the disease now known as anaplasmosis is contained in the famous report by Theobald Smith and Fred L. Kilborne on the cause and method of transmission of so-called Texas or southern cattle fever, published in 1893 (Bulletin No. 1, Bureau of Animal Industry). In this report are
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detailed accounts of anaplasmosis and another disease, piroplasmosis or tick fever.

Anaplasmosis was encountered frequently by Smith and Kilborne, and the question arose as to whether they were dealing with two different diseases. They found, however, that the course and events in the diseases were similar. They concluded that anaplasmosis was a type of piroplasmosis in which some unknown factor interfered with the normal development of the parasites. They concluded that Texas fever was transmitted by the cattle tick, *Boophilus annulatus*; it is assumed that they were referring to both types of Texas fever, which would include anaplasmosis. Primarily because the cattle tick was found to transmit Texas fever, preparations were made and a campaign to eradicate the cattle tick was begun in 1906.

Arnold Theiler, an investigator of animal diseases in Africa, presented good evidence in 1910 to show that Smith and Kilborne had been dealing with two separate diseases, piroplasmosis or tick fever, and another, which he named anaplasmosis.

K. F. Meyer recognized anaplasmosis in 1913 from experimental infections that he brought about in cattle in the United States.

Anaplasmosis was given no further special attention in the United States, however, until 1926, when P. B. Darlington reported that it was a troublesome disease in southeastern Kansas and that he failed to find cattle ticks on the affected animals. For the first time, therefore, the cattle industry was alerted to the fact that the eradication of the cattle tick was not eliminating anaplasmosis. Subsequently the disease was reported from areas outside the original boundaries of Texas fever. The Federal Government and several States thereupon began investigations to determine how anaplasmosis might be controlled and eliminated.

Economic losses from anaplasmosis in the United States probably amount to millions of dollars each year. The disease is most prevalent in the southern part of the country where piroplasmosis or tick fever was formerly coexistent with it, and it occurs sporadically though not infrequently in other areas. It is encountered usually in the warm months from June to November, especially in the late summer or early fall. Cases occur occasionally in winter.

Anaplasmosis is most severe in mature cattle. As many as 50 percent of the affected animals have died in some outbreaks. The disease is usually mild in calves and may therefore be unnoticed.

The parasites apparently destroy or cause the red blood cells of the infected animal to be destroyed. Here follow various degrees of anemia and weakness, which interfere with the animal's normal physiologic processes. In cases of long standing, bile pigments accumulate in the various tissues. It is not known whether the parasites produce toxins. Evidence that some kind of poisonous material is present is provided by the fact that a pint or more of blood from clinical cases produces symptoms of shock and sometimes even death when injected into the blood stream of a noninfected animal.

Little is known concerning the parasites that cause bovine anaplasmosis. Except when infections are started by experimental inoculation of extremely large amounts of blood containing parasitized red blood cells, 2 to 4 weeks or more elapse from the time of inoculation to the time that anaplasma are first observed in the blood of a newly infected animal.

During this prepatent period—the period before the parasites can be found in the blood—nothing is known as to where the organisms are located or what they may be doing. They may not produce any noticeable effects on the host during this period.

The parasites that occur in red blood cells range in size from about 0.2 to 0.9 micron. (An inch contains 25,000 microns.) During the course of the disease, the parasites apparently enter...
the red blood cells and increase in size and undergo a type of division characteristic of certain Protozoa. The largest are each divided into eight small, spherical bodies. The smaller parasites are each composed of a single mass of living material.

After the parasites first appear in the blood, the population increases for about 7 to 13 days and then starts to decrease. After it has declined for about the same number of days, it may increase for a few days and then drop again. The population of the parasites may fluctuate in this manner for months. Finally no more red blood cells are parasitized, as far as can be determined with the microscope. They may reappear in small numbers in the red blood cells at some distant and unpredictable time, however.

The anaplasms occur in their greatest numbers in the first parasitic attack. This is the only time when the damage may be severe enough to produce visible symptoms of anaplasmosis and sometimes death. Usually one or two parasites are found in mild infections in a single red blood cell; in severe infections, six or seven may be in a single cell. After a red blood cell becomes parasitized, it disappears in 3 or 4 days from the circulating blood.

Symptoms of Anaplasmosis vary greatly in severity and duration, depending on the severity of the anemia and its duration. With the exception of fever, which may occur even before parasites are found in the red blood cells, the onset of symptoms occurs at about the time (or within a few days) the peak of the infection is reached and anemia is worst. Symptoms gradually disappear when the red blood cell count improves noticeably, and the anemia subsides.

Symptoms may be as severe in animals that will recover as in those that will die from the disease. The principal symptoms are sudden loss of condition, increased pulse and breathing, and paleness of mucous membranes. As the disease progresses, there is drooling from the mouth, a discharge of thick mucus from the nostrils, progressive weakness, and cessation of rumination and defecation.

The severity and duration of the disease varies greatly. Sometimes the disease may be subclinical—so mild that it is unlikely to attract attention. This form is found most frequently in younger cattle. Calves may become stunted or unthrifty because of it.

In other cases the disease may run a severe course. More than half of the red blood cells may be parasitized at one time. The animal may die within about 24 hours after symptoms first appear. This peracute form occurs in some of the older, mature cattle, especially dairy cattle.

In still other cases, the disease may run a longer course. A variable number of red blood cells is parasitized at the peak of the infection. Symptoms may vary in intensity. Death or quick recovery may follow. This acute form occurs in cattle of all ages.

In some animals the disease may last a week or more and end in death or the beginning of a slow recovery. This chronic form occurs in some animals about 3 years old or older. Its long duration is due primarily to their inability to regenerate red blood cells fast enough.

A postmortem examination of animals that have died of anaplasmosis shows the blood to be thin. Small hemorrhagic spots usually appear on the outer surface of the heart and sometimes throughout the viscera. The gall bladder is filled with thick bile. The liver has a yellowish discoloration. The spleen is enlarged, and its contents have the appearance of blackberry jam. The flesh of an animal that has died shortly after the onset of symptoms may appear normal. An animal that has died after a lengthy siege of anaplasmosis may be greatly reduced in flesh, and the fat and viscera have a yellowish discoloration.

No specific medicinal treatment for anaplasmosis is available.
Two antibiotics, oxytetracycline and chlortetracycline, suppress the multiplication of the parasites and can rid carrier animals of infection. The drugs do not stimulate the formation of red blood cells and therefore do not show marked beneficial effects when used for treatment of clinical cases. It is reported, however, that mortalities are reduced and recovery is more rapid following treatment with them.

Blood transfusions are beneficial in the chronic form of the disease and may be useful in many cases in the acute form. To be effective, 2 to 3 gallons or more of whole blood must be injected into the sick animal. The blood can be transfused or transferred directly from one animal to another, or it can be let into vessels containing an anticoagulant, such as sodium citrate, and then administered. Blood from carrier animals as well as blood from uninfected cattle can be used. As much as 1 gallon of whole blood can be removed from a large animal without risk of injury.

Sick animals should be isolated from uninfected animals, protected from biting insects by the use of sprays, and kept in the shade. They should be provided with fresh water and a succulent or green feed.

**Immunity** in anaplasmosis is similar to that in some protozoan diseases, in that once an infection is acquired it is usually carried for a long time—in most cases of anaplasmosis, for the life of the host. All cattle are receptive to anaplasmosis, regardless of their age, and once they lose the infection they become receptive to infection again. Reinoculation of an animal carrying the infection has no appreciable effect on it, however.

Efforts have been made to produce a vaccine that would protect an uninfected animal against anaplasmosis without infecting it, but the results have not been satisfactory.

It is the practice in some countries to “premunize,” or artificially immunize, cattle against anaplasmosis before they have had the opportunity of acquiring the infection naturally. The cattle are inoculated with infected blood and allowed to go through the throes of the disease under conditions favorable for the survival of the affected animals. Some are inoculated in calfhood or at a time when the disease is likely to run a mild course. A strain of the parasite that affects the animal less severely than the regular strains of the parasites was found in Africa in 1911. It has been maintained and used in infecting cattle to protect them from the ravages of the injurious form. This strain sometimes is called *Anaplasma centrale* and sometimes *Anaplasma marginale* var. *centrale*.

**The manner** in which anaplasmosis is spread under natural conditions is mostly an unsolved problem. We have reports that some calves born of infected mothers became infected before birth, but we have no information as to the part these prenatal infections may play in the spread of the disease.

The causative agent does not occur in the feces or urine of infected animals. The disease is not contracted through contact with an infected animal. The parasites are present in the blood of all infected animals, even when they cannot be found by blood examinations, as is the case at most times in carrier animals of long standing.

It is remarkable how readily the disease is transmitted to uninfected animals by such operations as dehorning when proper precautions are not taken to clean the instruments each time they are used on a different animal. Even such small instruments as bleeding needles or needles used in vaccinations can transfer the disease from an infected to an uninfected animal unless they are sterilized each time they are used.

Experiments have shown that bloodsucking insects, such as mosquitoes and horseflies, can readily transmit the disease from clinical cases when the insects are allowed to feed for a few minutes on an infected animal and
then are quickly transferred to an uninfected one and allowed to finish feeding on it. The parasites may reappear in small numbers in the blood of a carrier animal as long as 11 months after the animal was first inoculated. Horseflies feeding on the animal at that time and then on a clean animal can transmit the disease to it.

Experimental studies with various ticks remaining in the United States after the eradication of the cattle tick have incriminated seven species of them as possible vectors of anaplasmosis in this country. They are the fowl tick, Argas persicus; the American dog tick, Dermacentor variabilis; the Rocky Mountain spotted fever tick, Dermacentor (andersoni) venustus; the Pacific coast tick, Dermacentor occidentalis; the winter tick, Dermacentor albipictus; the brown dog tick, Rhipicephalus sanguineus; and the black-legged tick, Ixodes scapularis.

Unlike experimental transmissions by insects of anaplasmosis, which involves the quick transfer of infective material from the source animal to the susceptible one, tick transmission involves the survival of the infective material in the ticks for days or even months. During this time it is possible that multiplication of the causative agent takes place.

In some experimental transmissions, ticks in one stage of development were removed from an infected animal and some time later were placed on susceptible animals. In some cases, ticks in one stage of development were allowed to engorge on an infected animal and then were allowed to undergo further development or moulting before they were placed on the susceptible animals. In the case of certain ticks, for example, Boophilus annulatus and Dermacentor (andersoni) venustus, transmission of anaplasmosis was accomplished by allowing the adults to feed on infected animals and then allowing the progeny of these ticks to feed on susceptible animals; in the latter cases, the tick eggs contained the causative agent of anaplasmosis. About 15 species of ticks from various parts of the world can transmit anaplasmosis under certain conditions. One or more of them may be an important reservoir of the causative agent of anaplasmosis under natural conditions.

Carrier animals are suspected as being the reservoir and source of infective material responsible for new outbreaks of the disease. Attempts have been made consequently to find a suitable method of detecting them so that they may be eliminated from herds. As a result, a diagnostic test based on the principle of complement fixation has been perfected.

The test has been used in field surveys to determine the prevalence of anaplasmosis in cattle in various parts of the United States. It has revealed that there are more infected cattle in some places than was at first suspected. Plans were made to use the test in a program designed to control anaplasmosis in the Hawaiian Islands for the first time on a large scale.

The outlook for the control of anaplasmosis in the United States is encouraging. After years of effort, drugs capable of destroying the parasites have been found, blood transfusions have been a valuable aid in treating sick animals, a complement-fixation test of high efficacy is available for detecting carrier animals, and certain ticks and biting insects have been shown to be capable of transmitting anaplasmosis under certain experimental conditions. It appears, therefore, that tools are now available for the beginning of a concerted drive against this disease.

It is possible that eradication of the carrier animals may eliminate anaplasmosis. It should be remembered, however, that ticks might act as reservoir hosts of the parasite. In combating this disease, care should be taken to clean properly all surgical instruments, bleeding needles, vaccinating needles, and dehorning instruments after each use. Animals known to be infected should be isolated, sprayed with fly repellent.
in the warmer months, and should either be sent to slaughter or treated to destroy the carrier state.

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**Hyperkeratosis**

**AUBREY M. LEE**

A NEW and strange disease of cattle was first seen and reported by Dr. Peter Olafson, of the New York State Veterinary College, in 1941. It was called hyperkeratosis, or X-disease—"X" being a symbol for the unknown and "hyperkeratosis" indicating the increased amount of keratin, or horny material, that develops on skin of the neck, shoulders, and withers in chronic cases.

This ailment was reported in 10 States in 1946. A year later it was known to exist in 27 States. Officials of the Department of Agriculture and of Southeastern States in 1948 investigated 26 affected herds in 20 counties in Alabama, Florida, Georgia, Tennessee, and Virginia. They found an average loss of 4,200 dollars per herd.

The disease was causing an estimated loss of 2 million to 4 million dollars a year by 1949. Deaths were highest—up to 80 percent—in calves less than 6 months old. About 50 to 60 percent of older calves died. The mortality in adult cattle was 10 to 35 percent.

In Texas the disease was diagnosed in 53 counties by 1950. In Wisconsin in June 1952 we had reports of 1,085 cases among cattle on 268 premises; an estimated 10,000 calves died in the winter of 1952. In Illinois 33 herds were affected. Tennessee reported more than 3,000 cattle had died or had to be slaughtered before 1952 because of the hyperkeratosis. About 20,000 animals were affected in Texas and 5,000 in Oklahoma in the winter of 1952-1953.

The disease then had been diagnosed and reported in 35 States, and in 4 more States it had been suspected in a herd or two. No new cases of hyperkeratosis of cattle were reported to the Department of Agriculture in 1954 or 1955—an indication that it had been