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A STUDY OF SURRA FOUND IN AN IMPORTATION OF CATTLE, FOLLOWED BY PROMPT ERADICATION.

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PRELIMINARY REMARKS.

About thirty years ago a number of the so-called Brahman cattle of India were introduced into southern Texas by A. H. Pierce, a stockman of Pierce, Tex. These animals were crossed with our domestic cattle, and the resulting influence on the herds was markedly apparent. One of the most interesting observations was that their progeny remained relatively free from ticks while other stock in the same pastures would be literally covered with these pests. The cattle ticks are present in such enormous quantities in this section of Texas as to make cattle raising much less profitable than it should be. This is due not so much to the fact that these ticks carry the Texas-fever micro-organism as to their great blood-sucking powers as external parasites. The Brahman grade cattle appear likewise to be less affected by other parasites and pestiferous insects such as mosquitoes, hornflies, gadflies, etc., and to withstand better the warm, dry climate and other semitropical conditions present in the gulf coast section of the United States than do the native cattle. Since this first importation by Mr. Pierce the Indian strain of blood has gradually deteriorated, and after his death one of the executors of the estate, Mr. A. P. Borden, requested a permit from this Department to make a further importation of Indian cattle for the Pierce ranch with the view of restoring this strain of blood.

It was claimed that the cattle on the ranch which had some Brahman blood in them were as a rule in good flesh, while the native cattle were in poor flesh and had to be fed in winter. They were likewise found to be less subject to the prevalent diseases of this section. However, while it is evident that Brahman cattle have their usefulness in semiarid localities, it is not believed that they will ever be considered important factors in our live-stock industry, for reasons that will appear elsewhere in this article.

In consequence of Mr. Borden's representations and his desire to introduce other cattle from India in order that the breed might be replenished and continued in Texas, the Secretary of Agriculture consented to allow him to make an importation from that country.

HISTORY OF THE IMPORTATION.

Appreciating the great danger to our live stock connected with the bringing of animals from India, on account of the very dangerous contagious diseases which prevail there and their general dissemination, the Department required the strictest possible precautions to prevent the introduction of any of these contagions. Dr. William Thompson, a veterinary inspector of this Bureau, who had served two years in the veterinary service of the Philippine Islands, was detailed to go to India to inspect the animals before purchase, to inquire into the history of the cattle as far as possible, and to accompany them on the steamer to the United States, his expenses being paid by Mr. Borden. Full and complete instructions were given both for microscopic examinations and for animal inoculations of the blood of these cattle, and strict orders were furnished to use the utmost vigilance in making inspections, and to accept no animals from any infected locality. Furthermore, it was stipulated that in case any infectious disease should be discovered after the animals had been collected for shipment the entire number should be considered as exposed and rejected. On this side a special isolated place for their quarantine was provided, and arrangements were made to transfer the cattle on arrival from the steamer to a barge by which they were to be transported to Simonsons Island, adjoining Staten Island, where they were to be kept in special quarantine for an indefinite period. This island is located on the Fresh Kills, a tributary of Staten Island Sound, about a mile from New Jersey, and separated from Staten Island by wide salt marshes subject to tidal overflow, so that the cattle would not touch the mainland until released from quarantine.

On March 31, 1906, Doctor Thompson and Mr. Borden met at Bombay and proceeded to Miraji, where 22 very fine bulls of the Krishna Valley breed were purchased. This section was reported to be free from rinderpest, surra, contagious pleuro-pneumonia, foot-and-mouth disease, and all other contagions. These cattle, in order to prevent their exposure on the way, were shipped in clean and disinfected cars to the government agricultural farm at Poona, where arrangements had been made to isolate the animals until ready for shipment from Bombay. Other purchases were made at Ahmadabad, where 9 head of range bulls of the Gugjurat breed were obtained, while 6 others of the Nellore breed were secured from Madras. The remainder of the importation, which altogether included 46 bulls, 2 cows, 1 heifer, and 2 calves, of seven different breeds, were selected in lots of one and two at various points along the route and then shipped to the Poona agricultural farm.

At Poona microscopic examinations of the blood for trypanosoma were made on two different occasions, as it was impossible to do so

prior to purchase owing to the prejudice of the Hindus. On account of the reported existence of rinderpest in other parts of West India it was considered advisable to inoculate all the animals with anti-rinderpest serum, and this work was carried out in order to guard against any unforeseen exposure during loading or detention in Bombay, or from feed and forage. From Poona the cattle were shipped in disinfected cars to Bombay, where they were conveyed by means of a loading chute directly from the cars to the steamer. Unfortunately, it was impossible to obtain rabbits for inoculation purposes in Bombay, nor could nose rings be purchased, and for these reasons no animal inoculations were made until the cattle reached the United States.

No indication of any disease being apparent in the cattle, and the history regarding the presence of any infectious disease in their places of origin being negative, the animals were shipped from Bombay on April 27 for Hamburg, where they were transshipped on June 2, arriving in port at New York on June 16, 1906, seven weeks after their departure from Bombay. They were transferred from the Hamburg-American steamer directly to a large barge by means of a cage and derrick, being hoisted from the steamer and lowered directly to the barge deck. The barge was then towed to Simonsons Island, which had already been prepared for the purposes of quarantine. A corral 100 feet square, constructed with 6 by 6 inch posts and 2 by 6 inch rails, had been erected with uprights joined to support a tarpaulin, which was used as a shelter from the sun and the rain. The 51 head of cattle were placed side by side on the east and south sides of this inclosure, as shown in figure 1. The cattle were stabled without accident, and appeared to be in very good condition on physical exam-

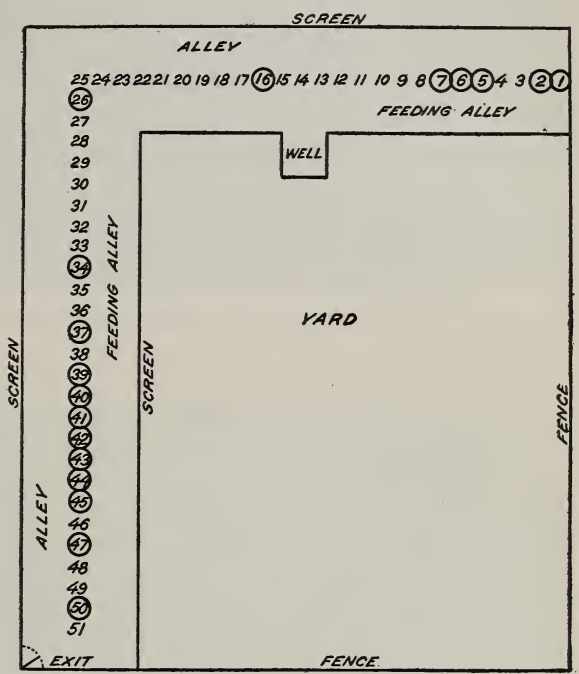

FIG. 1.—Corral with location of cattle therein. Circles around numbers indicate those animals which harbored the surra trypanosome.

ination. As the regulations of the Department provided for the tuberculin testing of all bovines imported into the United States, the cattle were subjected to this test as soon as they had thoroughly recovered from their sea voyage (June 29 and 30), but in no instance was any reaction obtained.

PREVIOUS IMPORTATIONS.

Brahman cattle were probably first introduced into the United States in 1849 by Dr. J. B. Davis, of South Carolina. Some additional importations for agricultural purposes followed, but such shipments were stopped in 1884 on the promulgation of an order of the Department of Agriculture issued under the act of Congress prohibiting importations of cattle from abroad without first obtaining a permit from the Department. After that time, until the Borden importation of 1906, no permits were granted to import Brahman cattle except for zoological gardens and menageries.

THE CHARACTERISTICS OF INDIAN CATTLE.

It will probably be of interest to mention briefly a few characteristics of this breed of cattle (*Bos indicus*), described in works on natural history as zebus and popularly known as Brahmans, or the sacred cattle of India. It is not uncommon to observe these animals in zoological gardens and circuses, but the majority of the sacred cattle on exhibition are of the smaller breeds, weighing about 250 pounds and standing not higher than 3 feet. On the other hand, the types of Indian cattle selected for this importation were of the larger breeds, standing as high as 6 feet and weighing up to 1,860 pounds. They are distinguished from our native cattle principally by the loose fold of skin at the navel, an immense hump on the withers, long, pendulous ears, large and loosely hanging dewlap, and an excessive fullness of the throttle. There is a more lengthened form of the head, with a concave line of profile, a mild, sleepy eye with a look of latent power frequently displayed, arched neck, and long, tapering legs. The horns are dark, short, but thick at the base, and point upward and backward; the hips are narrow, and the rump slopes rapidly from the sacrum to the tail. (See Pl. I.)

The sebum secreted by the sebaceous glands of the skin has a peculiar odor which seems to be repugnant to insect life. The hide, while it may be as thin as in our domestic animals, still appears to be much tougher and is more difficult to penetrate with a hypodermic needle. The hair is quite short and does not provide favorable shelter for the development of ticks. These three factors are probably responsible for the slight amount of tick molestation which these animals experience.

FIG. 1.—A ZEBU BULL OF THE BORDEN IMPORTATION, IN QUARANTINE.

FIG. 2.—TWO ZEBU CALVES OF THE BORDEN IMPORTATION, IN QUARANTINE.

The color of the Brahman cattle is chiefly light silver gray, with dark shadings of the fore and hind quarters. (See Pl. II, fig. 1.) However, the color varies much according to the breed, some being red, while others are white, and the albino bulls constitute the so-called sacred bulls of India, which play a very important part in certain religious festivals. Among the Hindus the zebu is believed to have a charmed life. They venerate this animal and hold its slaughter to be a sin, though they have no scruples about working it. While the Brahmans are classed as a distinct species, they cross readily with our domestic animals. In India these animals are not only reared for milk and flesh, but are also extensively employed as beasts of burden. They are likewise used for both riding and driving, having great powers of endurance. The hump is considered the most delicate part of the carcass for food, and is usually prepared in pickle, like tongue. The cows sometimes yield a fair amount of milk, but it is low in butterfat.

APPEARANCE OF SURRA IN THE UNITED STATES.

Despite the fact that the blood of all the Indian cattle in the Borden importation had been examined microscopically on two occasions at Poona, and twice again during the ocean voyage en route to New York, with negative results, it was deemed advisable and a necessary precaution to make the more exacting test of rabbit inoculations before accepting the cattle as free from the surra parasite.

With this end in view a sufficient number of rabbits were taken to Simonsons Island and one rabbit was inoculated with the blood from each animal. Cover-glass preparations were likewise made at the same time for examination of the fresh, unstained specimens. These blood inoculations were commenced on July 5 and 6 by the inoculation of 49 rabbits with the blood of adult cattle, the two calves not being tested at this time.

The method of taking the blood and injecting the rabbits for this and all subsequent tests was as follows: Each zebu was secured by a nose ring or halter to a head rail, the hair on the margin of the left ear clipped, and the tissue toward the tip of the lower margin washed and disinfected with carbolized water, dried, and the ear then whipped by the hand to render the blood vessels turgid. A small vessel near the margin was then nicked with the point of a knife and 5 to 8 c. c. of blood obtained in sterile bottles, each containing a sufficient quantity of potassium citrate solution to prevent clotting. When necessary the hemorrhage was arrested by the use of a figure-8 suture after sufficient blood had been obtained. After each operation the knife and hands of the operator were washed in a 5 per cent solution of carbolic acid. Identification cards were made out for each rabbit, to which a number was given corresponding to the num-

ber of the animal from which the blood was taken, and 2 c. c. of this blood was injected subcutaneously into the rabbit on the inner side of the thigh. The syringe used for this purpose was disinfected after each injection with 5 per cent carbolic acid and then rinsed with sterile water.

A few days later the temperatures of the rabbits were taken. Following the first inoculation tests, rabbits Nos. 16, 39, and 42 showed a marked rise. The blood of each rabbit was then examined microscopically, and the *Trypanosoma evansi*, the causative agent of surra, was demonstrated on the ninth day in rabbit No. 16, and on the tenth day in rabbits Nos. 39 and 42. (See fig. 2.)

It is our opinion, which appears to be confirmed by the following notes, that in all probability there were only these three infected zebus at the time of the arrival of the cattle in quarantine, and that the others became subsequently infected by means of the plague of flies present that summer in the vicinity of Staten Island.

The seriousness of the appearance of surra in the United States being apparent to all interested parties, the question of preventing the landing of any of the cattle was carefully considered, with the result that it was finally decided to kill and burn all the infected cattle and to make repeated blood tests of the remaining animals under proper precautions until it was absolutely proven that the infection had been entirely eradicated. As the importer, Mr. Borden, was at that time in Texas, a delay of several days was occasioned awaiting his arrival, but the killing and burning of the three infected cattle was accomplished on July 20.

THE CAUSATIVE AGENT OF SURRA.

It has been definitely shown by numerous experimental observations that surra is caused by the presence of the *Trypanosoma evansi* in the blood. This fact was first reported by Dr. Griffith Evans in 1880, and since then has been confirmed by many other investigators. The parasite is a flagellate protozoan 20 to 30 μ long, 1 to 2 μ broad, and approximately spindle-shaped in outline. (See fig. 2.) Each organism has a somewhat pointed posterior extremity, while the anterior extremity narrows into a long, wavy flagellum. The organism moves, as a rule, with the flagellum end forward, owing to the rapid lashing of this whip-like extremity and by the contractions and relaxations of the body. The micronucleus or blepharoplast or centrosome is prominently located near the posterior end and is connected with the flagellum by a distinct line passing along the free border of the undulating membrane, which is along one side of the parasite like a fin. The nucleus is near the anterior end. Multiplication takes place by longitudinal division only, the centrosome being

the first to begin dividing. The division of the nucleus follows, as a rule, the flagellum remaining attached to one of the resulting halves, while a new flagellum develops on the other half.

The parasite is transmissible from infected to healthy animals by biting flies, and perhaps by other agencies. Owing to its large size and active motility it is readily detected in a film of fresh unstained blood with the low-power lens of the microscope. At first there is noticed an intermittent and characteristic agitation of some of the red cells, and upon focusing in the vicinity of this motion there will soon emerge to view a minute, eel-like organism two or three times as long as the diameter of the red cell, actively moving between the blood cells. It appears in the blood in swarms, so that the examination of the blood at one time may give negative results, while a similar examination made earlier or later may give positive results. The organism, however, is invariably found during the paroxysms of the disease in both experimentally and naturally acquired surra. When such blood is filtered through bougies the filtrate is not pathogenic, proving that the trypanosome is withheld by the filter.

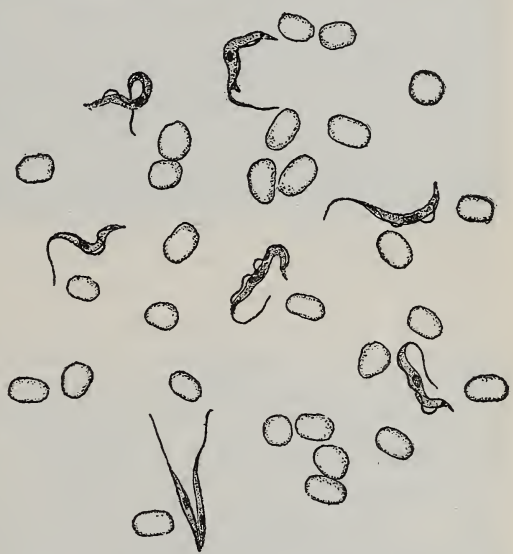

FIG. 2.—*Trypanosoma evansi*, the cause of surra. (From Zebu No. 44.)

The disease may likewise be transmitted from one susceptible animal to another through a long series, and in each instance the trypanosome may be observed during the febrile attack by microscopic examination. Even during the intermission when the blood appears to be entirely free of the trypanosomes the inoculation of rabbits will, as a rule, result in the production of the disease. All attempts that have been made in the laboratory of the Pathological Division to cultivate the organism on the blood-agar medium of Novy, as well as by other methods, have been without result, although the cultivation of certain other species of trypanosome (*T. lewisi* and *T. equiperdum*) has been accomplished.

The exact method by which these parasites interfere with the health of the infected animals has not as yet been established.

NATURE OF THE DISEASE.

The term "surra" was given to this disease by the natives of India, and was adopted by Evans, Lingard, and others on account of its appropriateness. The word "surra," by which the disease has since been universally known, was used by the natives to describe anything withered or rotten, such as a decayed carcass. They applied the term loosely to all those chronic ailments of a devitalizing character which had no specific designations. The name was thus very comprehensive, and was applied to this specific disease of animals because there is a marked withering or falling off in condition without sufficient post-mortem lesions to account for it. It is a disease of the Far East, and has prevailed in certain sections of India for generations. It has been reported from the Persian Gulf, Korea, Egypt, Syria, Algeria, Zululand, Java, Borneo, Madagascar, Mauritius, Burma, China, the Philippine Islands, and other places.

Surra is a specific, communicable febrile disease occurring in horses, mules, asses, camels, elephants, dogs, and rats, and capable of being transmitted by inoculation to cattle, buffalo, sheep, goats, rabbits, guinea pigs, and monkeys. It is due to the presence of a specific flagellate parasite in the blood, the *Trypanosoma evansi*, named after its discoverer. The fever is of an intermittent, remittent, and sometimes relapsing type, and continues for varying periods from a few days to months, depending upon the animal attacked and its physical condition at the time. In solipeds the disease generally assumes an acute type and causes death in a relatively short time, while in camels the disease is of a chronic type and the animal may live for months or even years, frequently recovering if the disease lasts for three years. The blood of cattle may swarm with the trypanosome without apparent harm, although the animals may become very thin and anemic for a time, after which they, as a rule, recover, though they occasionally die. The great danger from infected cattle, however, is in the possibility of the infection being carried from the apparently healthy cattle to the highly susceptible horse, mule, or ass by flies or otherwise. The period of incubation is usually about six to eight days after the exposure, although the disease may develop in from two to seventy-five days.

All available evidence seems to indicate that the most common method of transferring the trypanosome of surra from infected to uninfected animals is by means of insects, particularly the biting flies. Infection may likewise take place through an abraded wound on the body becoming contaminated with infectious blood. Thus dogs and cats with abrasions of the mucous membrane of the digestive tract may contract the disease by eating the flesh of horses which have died of surra. Saddle galls, summer sores, and similar lesions on otherwise healthy horses may likewise become infected by birds

FIG. 1.—A ZEBU BULL OF THE BORDEN IMPORTATION, ON THE RANCH IN TEXAS.

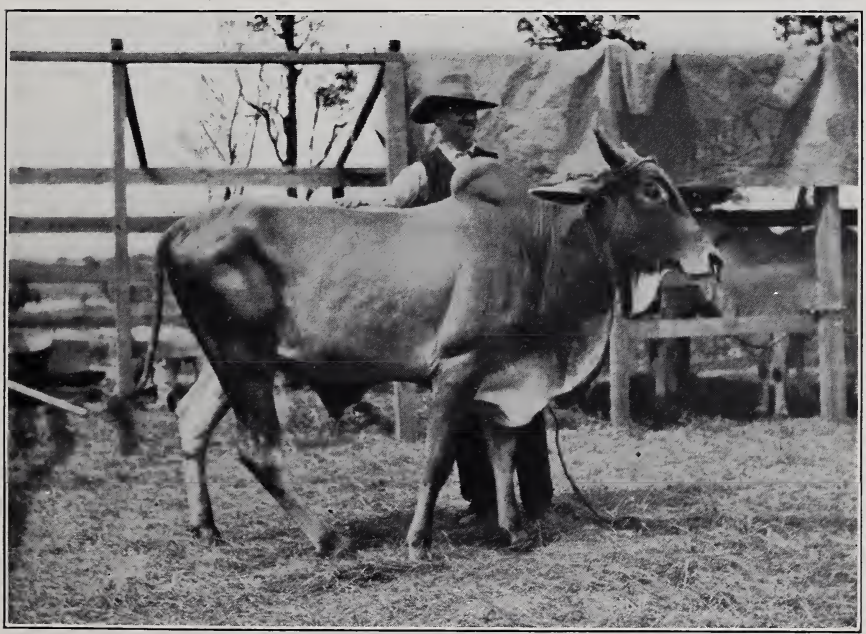

FIG. 2.—A ZEBU BULL WHOSE BLOOD WAS FOUND TO BE INFECTED WITH THE TRYPANOSOME OF SURRA.

HORSE, SHOWING SWOLLEN AND EDEMATOUS CONDITION OF EXTREMITIES, SHEATH, AND UNDER SURFACE OF ABDOMEN, ON NINETEENTH DAY OF THE DISEASE. (AFTER LINGARD.)

and insects which peck or feed on them after having previously soiled their beaks or probosces on infected animals or carcasses. Drinking stagnant water and eating grass or other forage grown on recently inundated land are popularly regarded as being methods of infection with surra, but the experimental proof to support such opinions is lacking. Stiles has probably given the correct interpretation of this theory by drawing attention to the fact that biting flies are generally numerous around inundated pastures and stagnant water, and therefore a great number of possible transmitting agents of the disease are in these localities.

In the outbreak of surra here recorded it was quite definitely proved that the infectious principle was carried from animal to animal by the large breeze fly, *Tabanus atratus*, and by no other species of fly or other kind of insect; nor did contact exposure, the use of the same drinking buckets, etc., play any part in the spread of the infection.

According to Lingard,[a] the chief symptoms in the horse are an intermittent, remittent, and sometimes a relapsing type of fever which continues for a varying period from a few days to several months. Closely following the first rise in temperature there is the occasional appearance of urticarial eruption, which may make its appearance at any time during the course of the disease. Then follows the presence of petechiæ on the mucous membranes, chiefly those covering the membrana nictitans; also nasal, ophthalmic, vaginal, and other mucous discharges, and the exudation of a yellow semigelatinous material in the subcutaneous and other connective tissues, especially of the legs, breast, and abdomen. (See Pl. III.) There is rapidly advancing anemia, emaciation, and great debility, although in the large majority of cases the appetite remains good throughout, no matter how high the fever may be. There is extreme pallor of the visible mucous membranes, followed at a later period by a yellow tinge. From first to last there is a progressive wasting.

The blood at first presents a normal character, but after a varying period of time undergoes marked changes. The white corpuscles are increased in number, while the red cells usually cease to form normal rouleaus, lose their individuality, and run together, forming irregular masses which are first of a dark appearance but gradually become pale owing to the loss of coloring matter as the disease advances.

The presence of the flagellate is not continuous during the whole course of the disease. At first it is usually found in small numbers in the blood, but it increases with greater or less rapidity until, having attained a maximum, it disappears either gradually or suddenly, to

[a] Lingard, Alfred. Report on horse surra. Bombay, 1893.

reappear after an interval. The periods during which it may be observed in the blood by microscopic examination are marked by extreme irregularity, varying from one to six days, though the latter number is very unusual.

The disease is invariably fatal in horses, death usually being due to exhaustion, but sometimes to concurrent complications. After death no specific lesion is present, but as a rule there are small subpleural, subendocardial, and subperitoneal extravasations, together with enlargement of the liver and spleen. If death takes place during a paroxysm the hematozoan will be found for a certain time in the blood. (See Lingard, 1893, pp. 1–2.) There is also an edematous exudate into the cellular tissues of the legs and abdomen, and the lymph glands are edematous and enlarged. The kidneys are congested and edematous or the seat of blood extravasation. Gastric ulcers have been noted preceded by capillary embolism and congestion.

In cattle affected with this disease the trypanosomes are frequently found in the blood before the animals show outward symptoms. (See Pl. II, fig. 2.) During this time, however, they serve as a means of spreading the disease. It is interesting to notice that in cattle the affection, unlike the affection in solipeds, is relatively benign, and many cattle, after having the disease for a time, recover. The first noticeable symptom is dullness followed by progressive emaciation with slight temperature variations. Under the breast and abdomen may be noted occasional areas of edema, accompanied by mucopurulent inflammation of the conjunctiva, cornea, and nasal mucosa. Lingard has stated that, although during the paroxysms of the disease the blood of the bovine species teems with the hematozoan, and their bodies become extremely emaciated, nevertheless the cattle usually recover from an attack and in time put on flesh and appear in robust health.[a]

However, cattle seem to vary in susceptibility to the fatal effects of surra in different countries. For instance, when surra was introduced into the Island of Mauritius in 1901 by an importation of Indian cattle, 70 to 80 per cent of the native cattle, it is said, later succumbed to the disease. It must be remembered that in tropical countries the transmitting agencies are present to some extent all the year round, the disease being spread more actively during the rainy season, owing to the larger number of flies present and to the humid state of the atmosphere, which favors greater dissemination.

[a] For a detailed account of surra the reader is referred to Bureau of Animal Industry Bulletin 42, or to the same article in the Eighteenth Annual Report of the Bureau, entitled "An emergency report on surra."

PROMPT ERADICATION OF THE DISEASE.

As the decision had been made to destroy only those cattle of the Borden importation which harbored the trypanosome of surra, the first step taken after the killing and burning of the three infected zebus was to protect the remaining cattle from the biting flies and mosquitoes which swarmed around the corral in countless numbers. Therefore on July 24 was commenced the flooring and screening of that portion of the corral occupied by the cattle, and this work was accomplished July 27.

While the inclosure was being screened the cattle were necessarily removed from their original positions and placed temporarily in the open along the north and west sides of the corral. On completion of the screening of the south and east sides of the corral an abundant supply of sticky and poisonous fly paper was spread about within the inclosure, and very shortly all the *Tabanus atratus* were caught or destroyed, along with large numbers of the other Tabanidæ and *Stomoxys calcitrans*, one of the Muscidæ. However, a considerable number of the latter species and a few *T. lineola* and *T. costalis* still remained, and it seemed impossible to eliminate them by this temporary screening.

The second series of inoculations was made on July 31, the results of which were anxiously awaited, as upon the outcome depended the fate of the entire herd. The hope was entertained that if the Tabanidæ were solely responsible for the spread of the infection (which dissemination was expected under the circumstances), there were prospects of saving some of these valuable animals brought at great risk and expense 10,000 miles over the seas. On the other hand, should the other species of flies, which were far more numerous and very difficult to eliminate, be found to be active disseminators of the disease, the hopes of saving even one animal would have to be abandoned. On the expiration of this test, which gave seven reactions (Nos. 48, 1, 2, 50, 34, 41, and 44), it was decided that it was possible eventually to save part of the herd by placing each animal in an individual fly-proof stall, and by eliminating the infected cattle by blood inoculations of rabbits. After this second test it seemed plausible to consider that only the Tabanidæ—and probably only the *Tabanus atratus*—were responsible for the spread of the infection, and that the disease would be eradicated with the elimination of those animals which had been infected by these flies previous to July 27, when this *Tabanus* was effectually excluded as a factor in the conveyance of the infection.

A specially constructed fly-proof stable containing individual fly-proof box stalls was therefore erected for the purpose of eliminating all kinds of flies, and especially the stable fly, *Stomoxys calcitrans*,

considered by some authorities as being capable of transmitting trypanosomal infections. This stable was completed on August 15, by working three shifts of carpenters, and during its construction the third (August 6) and fourth (August 11) tests had been made, resulting in the reaction of four animals in each test.

The appended table shows the positive results of the blood inoculations.

Positive reactions of rabbits to surra, following inoculations with blood of zebus.

Date of inoculation.	No. of animal.	Date of diagnosis.	Period of incubation.
First test, July 5 and 6	39	July 15	Ninth day.
	42	July 16	Tenth day.
	16	...do	Do.
Second test, July 31	43	Aug. 6	Sixth day.
	1	Aug. 7	Seventh day.
	2	...do	Do.
	50	...do	Do.
	34	Aug. 9	Ninth day.
	41	...do	Do.
	44	...do	Do.
Third test, August 6[a]	26	Aug. 11	Fifth day.
	40	Aug. 12	Sixth day.
	6	...do	Do.
	47	Aug. 15	Ninth day.
Fourth test, August 11[b]	45	...do	Fourth day.
	5	Aug. 16	Fifth day.
	37	Aug. 18	Seventh day.
	7	Aug. 20	Ninth day.

[a] In addition to those recorded in this test, Nos. 1, 43, and 44 repeated their reactions of the second test, while rabbit No. 50 died before trypanosomes were found. Nos 2, 34, and 41 did not repeat in the third test.

[b] Besides these original reactions in the fourth test, Nos. 6, 26, and 47 of the preceding test repeated, while rabbit No. 40 died on August 22 without showing any trypanosomes. These unintentional retests occurred in the third and fourth series owing to the inoculations being made so close together that the rabbits in the preceding test had not time to react before the next series was injected.

The cattle shown to be infected with surra by these reactions in the inoculated rabbits were destroyed immediately upon the recognition of the trypanosome in the rabbits' blood. Owing to heavy rains several of the cattle were buried instead of burned, their bodies being destroyed by covering with unslaked lime and pure sulphuric acid, but in no instance was a post-mortem examination permitted, on account of the danger of disseminating the infection.

On August 15 the remaining cattle were removed from the screened corral and placed in the individual fly-proof box stalls within the fly-proof stable already mentioned. No further inoculations were made until August 31; a test made then, and subsequent inoculations made September 7, 13, and 20, and October 10, 19, and 24, proved negative in every case. On September 7 rabbit No. 48 exhibited a pseudo reaction, due, as was demonstrated later, to an intercurrent disease.

In the inoculations confirmatory tests were not made prior to August 15, owing to the danger involved in keeping the infected

cattle alive; but it was noted that several cattle—for instance Nos. 2, 34, and 41—failed to repeat in giving reactions on the subsequent unintentional retest. These retests occurred in several instances where two series of inoculations were made so close together that the rabbits in the first test had not time to react before the next series was injected.

During the quarantine no reliance was placed upon the microscopic examination of blood smears made direct from the cattle, but it will be interesting to note that in two cattle numerous trypanosomes were observed by this method of examination. As the disease spread, the average period of incubation in the rabbits was shortened, and those rabbits which were not immediately killed upon reacting soon succumbed to the infection. Guinea pigs were also used in some of the tests, but proved unsatisfactory as compared to rabbits.

In view of the fact that the last seven series of tests were successively negative, and as killing frosts had already occurred, resulting in the disappearance of all flies and mosquitoes, it was recommended that the remaining cattle, 33 in number, be released from quarantine. On November 14, 1906, the Secretary of Agriculture issued a permit to that end, and the cattle proceeded directly to their destination in Texas.

RABBIT EXPERIMENTS WITH INFECTED BLOOD.

From this importation of surra much was learned of the character of the disease and of the remarkable periodical development of the living parasite within the blood of the affected animal. Virulent blood drawn from the affected animal and injected into a test rabbit will cause a sharp elevation of temperature after a period usually varying from four to nine days, occasionally extending to ten or eleven days, but averaging seven and a half days in our experiments. If an examination of the blood of the inoculated animal is made at the time of the acme of the fever attack, numerous wriggling and squirming organisms will be seen moving about rapidly among the blood corpuscles and manifesting their presence by an active disturbance of all corpuscles with which they come in contact. If the blood is examined daily these moving hematozoa may be found present for two, three, or four days, when they suddenly disappear, while the temperature returns to normal. Now follows a latent or quiescent period lasting for five or six days, during which the temperature of the animal remains at or near the normal point, and the animal eats as usual, only showing the effects of the parasitic invasion by a staring coat and by a slight loss of flesh and energy. At the end of the latent period the same course is repeated, and again an elevation of temperature and a return of the parasites occur, only to disappear more or less suddenly at the termination of the attack. These recurring

periods of disease gradually undermine the strength and vitality of the animal until it succumbs.

Post-mortem examination of such an animal shows, first, general emaciation, together with bare denuded patches about the eyes, mouth, and nose, from which the hair has fallen. The external genitals are swollen and edematous, and more or less bare of hair. On opening the carcass it will be seen that the skin is firmly adherent to the tissues underneath; that considerable clear serous fluid has entered the peritoneal cavity; that the abdominal viscera have formed numerous fibrous attachments to the peritoneal walls; and that similar little fibers unite the various visceral organs into a more or less compact mass. The spleen will be found greatly enlarged, even to six or eight times its normal size. The liver and all of the thoracic organs will usually be found unchanged. Variously scattered over the surfaces of the abdominal walls, both internal and external, may be found small collections of the débris of degenerated red blood corpuscles, and the outer surfaces of the digestive organs within the peritoneal cavity may exhibit scattered remains of similar hemorrhages.

For experimental purposes healthy rabbits were placed in cages with rabbits that had been infected through injections of virulent blood, but no infection followed, even though they remained in close contact for thirty days, eating and drinking from the vessels used by the diseased animals.

THE RÔLE OF THE TABANIDÆ IN THE TRANSMISSION OF SURRA.

According to Lingard,[a] it appears that the cattle of India, particularly plains cattle, like the camel and water buffalo, are relatively immune to the harmful or fatal effects due to trypanosomal infection, especially to *Trypanosoma evansi*. Unlike the camel and water buffalo, however, the parasites appear less frequently in the blood of Indian cattle, and sometimes at rather long intervals, accompanied by a slight rise of temperature. Practically all authorities agree that the blood of infected animals is as a rule infectious even during the incubation period. Accepting the general applicability of the above statement, the first test on July 5 and 6 shows that there existed at that time three centers of infection, and the writers are strongly inclined to believe that on arrival of the cattle on June 18 there were not more than these three infected animals in the herd. These animals may have been infected in India prior to their purchase, or on leaving Bombay, or while the vessel was moored to the dock at Kurachi from April 29 to May 5, inclusive, where a number of camel

[a] Journal of Tropical Veterinary Science, Vol. 1, No. 1, April, 1906.

trains were in close proximity and *Tabanus tropicus* were present on the cattle while in port.

It is the consensus of opinion of practically all authorities on surra that the several species of flies implicated in the transmission of the various forms of trypanosomiasis act only as mechanical transmitters or accidental carriers of the infection, and that no part of the life cycle takes place in the body of the fly. A review of the literature on the subject tends to prove that all forms of these diseases in domestic animals, which are disseminated by flies (with possibly the sole exception of nagana), are spread chiefly if not entirely by some species of the Tabanidæ.

From the time the Indian cattle landed on Simonsons Island until the corral was screened several species of flies were present.[a] Among these the *Tabanus atratus* deserves special mention, although the *T. lineola*, *T. costalis*, and the muscid *Stomoxys calcitrans* were also noted. The former is commonly known as the black horsefly, gadfly, or breeze fly, and is widely distributed throughout the United States. As the eggs are deposited in damp or marshy places and the larvæ are semiaquatic, the vicinity of the quarantine pen was very favorable for the presence and propagation of this species.

Tabanus atratus[b] emerge as adult flies as early as May and persist until September. These large black flies were numerous and very vicious in their assaults upon the cattle, which they attacked at their most vulnerable parts, principally the hump and over the spine. As many as seven of these flies could be seen on one hump. They were most active during the late afternoon on bright days and during the entire day on dark days. The mouth parts of the female are well adapted for deep piercing, and when in the act of drawing blood they appeared to stand on their heads. When dislodged by the efforts of the animals they passed directly to the next animal, leaving, when successful, a trickling flow of blood to follow the bite. While these flies were always in evidence about the cattle up to the time of screening the corral on July 27, they were entirely excluded after that date.

The green-headed horseflies, *T. lineola* and *T. costalis*, were more numerous than *T. atratus*, but less dreaded by the cattle, and were inclined to stay upon one host, attacking any part of the body, and less frequently causing blood to flow from their bites, and then only in small quantities as compared with the *T. atratus*. These flies were not entirely eliminated from among the cattle until August 15, when the fly-proof stable was completed.

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[a] The determinations of the species were made by the authors.

[b] For notes on the habits of this and certain other North American species of Tabanidæ see Technical Series No. 12, Part II, Bureau of Entomology, U. S. Department of Agriculture, 1906, "Habits and life histories of some flies of the family Tabanidæ," by James S. Hine.

The stable fly, *Stomoxys calcitrans*, was present in swarms, biting any part of the body, more particularly the thin skin below the knee and hock joints. They left a drop or so of blood following the bites. The swampy surroundings and decaying vegetation in close proximity to the corral furnished appropriate conditions for the rapid and numerous multiplication of these stable flies. Like the two previously mentioned species, these flies were only excluded after August 15, on the completion of the new stable.

After the second series of blood inoculations it was firmly believed that the Tabanidæ, more particularly *T. atratus*, were solely responsible for the spread of the infection, and that the disease would be eradicated with the elimination of those animals which had been infected by these flies previous to July 27, when this species was effectively excluded as a factor in the conveyance of the infection. The results of the tests of August 11, which were followed by negative results in all later tests, proved this belief to be well founded. Allowing for the period of fifteen days elapsing between July 27 (when the *T. atratus* was excluded by screening the corral) and August 11 (when the last series of injections was made which gave positive results) as the longest period for the incubation of surra in the cattle after the exposure to this *Tabanus*, and for the fact that large numbers of *S. calcitrans* and a few *T. lineola* and *T. costalis* were present in the inclosure from July 27 to August 15, a period of nineteen days, it will be admitted that the last three species played a small, if any, part in the transmission of the infection. Had these flies been capable in this instance of conveying the parasite to any extent it is evident that hardly one animal would have escaped becoming infected. Final results based on the theory that *T. atratus* was solely responsible favors the opinion that the cloth screening of the corral would have been sufficient if the presence of this *Tabanus* could have been prevented. Figure 1 shows location and total number of cattle that became infected in this interesting experiment.

The evidence herein submitted indicates that the transmission of surra in this outbreak was made possible by (1) the close proximity of the infected and exposed animals, (2) the presence of a species of the Tabanidæ, acting as an intermediary bearer, and (3) the warm and humid climate which prevailed at that time.

That the season was warm and humid during the period under discussion is borne out by the meteorological summary of the New York station of the United States Weather Bureau for the days between June 18 and July 31. During this period there were but six clear days, the maximum temperature averaging 81.6° Fahrenheit, and the relative humidity being above 80 on at least twenty-four of these days. By reason of this large number of cloudy and humid days prevalent during that time, the climatic conditions were very favorable for the activity of all species of flies, and the facility with which the trypanosomal infection could be conveyed from infected

to exposed animals without drying on the proboscis of the transmitting agent.

Fortunately, there was no spread of the infection outside of the original herd, because of the prompt screening and thorough isolation of the infected cattle, there being no other animals in the locality with the exception of one domestic cow and a calf kept on the premises. The latter, however, did not become infected, although they had grazed just outside of the corral and within 100 yards during the period from June 18 to July 20.

CONCLUSIONS.

1. In July, 1906, the first outbreak of surra in the United States was observed in an importation of zebus from India, and the disease was promptly eradicated by slaughtering and destroying the infected animals.

2. The causative agent of the disease is the protozoan *Trypanosoma evansi*, an eel-like organism which appears in the blood periodically in swarms. This parasite is transmissible from infected to healthy animals by biting flies, and possibly by other agencies.

3. Surra is a strictly infectious disease occurring in horses, cattle, sheep, and other animals, the transmission of which in this particular outbreak was dependent upon an intermediary agent, most probably a fly, the *Tabanus atratus*.

4. Contrary to some authorities, there exist in the United States, and probably in other temperate climes, species of Tabanidæ capable of transmitting trypanosomiasis, and which need not be the identical species implicated in the transmission of these diseases in countries where these infections are enzootic.

5. It has been definitely shown that in surra as well as in other trypanosomal infections microscopical examination of either stained or unstained blood films will not suffice in making a diagnosis, and that the only satisfactory results are obtained by animal, particularly rabbit, inoculations.

6. Relative to further importations into the United States of any class of susceptible animals from surra-infected countries for agricultural purposes or for menageries or zoological gardens, the experience gained in this outbreak indicates that it would be imprudent to import such possibly infected animals without testing each individual, either before or after arrival, by blood inoculations of susceptible small animals, preferably rabbits.

7. It will at once be evident that the spread of such a disease as surra over the country would quickly lead to great destruction of live stock and to great financial loss. To prevent these losses the best efforts of this Bureau have been exerted and the disease has been rigidly controlled and promptly eradicated.

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