

## THE SIGNIFICANCE OF COLOSTRUM TO THE NEW-BORN CALF.

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(Received for publication, March 31, 1922.)

The high mortality of calves during the 1st week of life has been the subject of researches for a number of decades. The chief symptoms preceding death are diarrhea, whence the name scours, inflammation of the umbilical stump (omphalitis), and multiple exudative arthritis. The concensus of opinion today is that there is a more or less close relation among these clinical manifestations and that, as pointed out by C. O. Jensen,<sup>1</sup> the chief infecting agents are races of *Bacillus coli*. In the latest summaries of handbooks covering this subject the emphasis is placed upon the infectious agents and all the measures that are recommended involve isolation, cleanliness, disinfection, and specific serum treatment.

Running parallel with these investigations but hardly influenced by them are studies on the transmission of immune bodies from mother to fetus and nursling. The fundamental studies of Ehrlich on ricin and abrin immunity transmitted to mice in the milk of immune mothers were followed by a series of investigations involving both normal and artificially induced antibodies in the mother's milk. These showed that not all species act alike, that some may transmit antibodies to the fetus *in utero*, others only in the milk.

The difficulty experienced in keeping calves alive which had not received colostrum from the mother led to a more thorough study of the effect of withholding this first milk. The significance of colostrum to the new-born calf is not set forth in medical or veterinary

<sup>1</sup> Jensen, C. O., in Kolle, W., and von Wassermann, A., Handbuch der pathogenen Mikroorganismen, Jena, 2nd edition, 1913, vi, 121.

literature with any definiteness. This fluid is generally assumed by some as necessary to cause evacuation of the fetal fluids and solids from stomachs and intestines. Others think that a cathartic like castor oil may replace it. In formulating measures for preventing calf scours Hutyra and Marek,<sup>2</sup> probably basing themselves on the work of C. O. Jensen<sup>3</sup> who stated in 1905 that calves die of enteritis if fed cooked or pasteurized milk during the first 24 hours of life, advise feeding the dam's colostrum for a day before heated milk is fed. They suggest that the fore milk be rejected since it might be infected. In the carrying out of the Bang system for the control of bovine tuberculosis, some have withheld colostrum, others have allowed the calf to suckle the dam immediately after birth, although the original method permits the calf to remain with the dam until it has taken the first milk.

Considerable work on the problem of feeding new-born calves has been done by W. L. Williams and associates.<sup>4</sup> Although the factor of colostrum entered, it was complicated with the use of scours sera and the boiling or pasteurizing of milk. No definite experiments on the simple exclusion of colostrum from the diet and the association with these of adequate controls by which the unknown, uncontrolled factors might be balanced are reported.

J. Traum<sup>5</sup> takes up the question of raising calves from a tuberculous herd by excluding the colostrum and milk of the reacting dam. Traum does not, however, state how many calves did not receive colostrum or milk immediately following the colostric period, for he writes that in the herd in which the experiment was going on "there were usually about 25 fresh cows yielding sufficient colostrum to frequently supply the calves born in reacting herd." Without doubt Traum did raise calves without colostrum, but he does not state the number as compared with those that did receive it nor give any subsequent history of the calves, nor does he report any losses by the way.

So far as it has been possible to examine the literature, the statement is warranted that no experiments dealing exclusively with the

<sup>2</sup> Hutyra, F., and Marek, J., *Spezielle Pathologie und Therapie der Haustiere*, Jena, 4th edition, 1920, i, 163.

<sup>3</sup> Jensen, C. O., *Z. Thiermed.*, 1905, ix, 121.

<sup>4</sup> Williams, W. L., et al., *Rep. New York State Vet. College*, 1914-20.

<sup>5</sup> Traum, J., *J. Am. Vet. Med. Assn.*, 1921, lix, 755.

withholding of colostrum have been made which at the same time include a number of controls sufficient to eliminate highly virulent epizootics of scours. For this reason it has seemed justified to record the following experiments with a certain number of details concerning the individual calves gathered together in an appendix.

#### EXPERIMENTAL WORK.

In order to balance as far as possible the many unknown factors entering into the undertaking, two experiments were carried on simultaneously. One group of calves was to have colostrum, the other not. The calves were obtained from the same large herd. To make sure that none that had suckled the mother soon after birth should be included in the group not having taken colostrum, only those born during the day and definitely known to the attendant to be without food were chosen. These were removed with as little exposure as possible to the Department units, a distance of  $1\frac{1}{2}$  miles. The calf was covered with a blanket, placed in a crate, and transported in a protected autotruck. The units were artificially heated. In the early experiments the calves were gently rubbed with cloths until nearly dry. Later they were washed with hot water containing some soda to soften the mucus adhering to the hair and thoroughly rubbed until dry. The umbilicus in later cases was snipped off if longer than 1 inch, gently manipulated to remove fluids, dipped in 0.1 per cent bichloride of mercury, and dusted with boric acid powder.<sup>6</sup> In some the bichloride was omitted. The milk was fed soon after milking and was raw in all cases.

The group which took colostrum comprised ten calves. All of these survived the danger period and were kept various periods of time thereafter. Three died unexpectedly after 25, 38, and 45 days respectively (Nos. 757, 694, and 715). The protocols indicate that death was most probably due to some kind of poison and experiments are under way to clear up if possible the cause of death. Whatever this cause may have been, the evidence is quite conclusive that there was no ordinary infection involved, since in the two from whose organs cultures were made bacteria could not be demonstrated even though in one case (No. 715), death having occurred early Sunday

<sup>6</sup> Williams, W. L., *Rep. New York State Vet. College*, 1913-14, 163.

morning, the autopsy was not made until after 28 hours refrigeration. A condition common to the three animals was the presence of punctiform hemorrhages throughout the intrathoracic portion of the thymus.

Of the second group of twelve calves which received no colostrum, nine died and three survived. These may be grouped according to the length of life. Seven of the calves died within 6 days. Thus four (Nos. 663, 685, 699, and 566) died within 3 days, one (No. 895) in  $3\frac{1}{2}$  days, one (No. 894) in  $4\frac{1}{2}$  days, and one (No. 665) in  $5\frac{1}{2}$  days. One (No. 682) not included in the figures was too weak to take food and died within 2 days.

Before considering the gross appearances presented at autopsy, it should be stated that in new-born calves minute hemorrhages are almost regularly encountered in certain organs. They are rarely absent from the auriculoventricular valves of the heart. These have been made the subject of special study by Laura Florence.<sup>7</sup> The mucosa of the leafy or expanded portion of the fourth stomach is regularly sprinkled over with petechiæ. The area involved varies from a few centimeters to the entire stomach. In some cases the hemorrhages are deep, in others superficial. Each spot is then capped with a bit of digested blood. Notably the pyloric valve is the seat of minute hemorrhages and in calves several months old shallow ulcers are occasionally still present on this valve. Less frequently the lowest 3 to 4 inches of the rectal mucosa is deeply congested and blood is now and then seen on the discharges. The ileocecal valve in rare instances is permeated with hemorrhages. In a few cases the mucosa of the rumen is involved in hemorrhages. If we except the heart valves, the hemorrhages, so far as studied, may be tentatively considered as mechanical in origin and due to conditions arising during parturition. Wherever in the present paper these hemorrhages are mentioned, the above facts should be borne in mind.

The appearances at autopsy differed somewhat from animal to animal and were due to differences in the blood content of the organs. The mucosa of the small intestine was in some instances pale, in others deeply congested in parts or throughout. The large intestine also varied in this respect. In all cases the small intestine was more deeply congested than the large. The other organs most involved were the kidneys. These varied from a nearly normal coloration and consistency to an intense congestion of the entire organ and a much firmer consistency. The urine taken from the bladder was free from blood or hemoglobin and contained only a trace of albumin

<sup>7</sup> Florence, Laura, *Am. J. Dis. Child.*, 1922, xxiii, 132.

with one or two exceptions. The liver cells usually contained more or less visible fat. The spleen was normal in size and flabby. The thoracic organs presented nothing characteristic.

Coming to the bacteriology of these cases we meet a definite condition in all animals. The spleen, liver, and kidneys contained large numbers of *Bacillus coli*. Each loopful of tissue fluid contained hundreds of bacteria. There was undoubtedly to a certain extent

TABLE I.  
*The Results of Feeding and Withholding Colostrum.*

No. of calf.	Colostrum fed +; not fed -.	Source of dam.	No. of pregnancy.	Source of milk fed.	Date of birth.	Died, killed, or sold.	Remarks.
663	-	Eastern.	1	601	Oct. 4	Died, Oct. 6.	<i>B. coli</i> septicemia.
664	+	Native.	1	600, 601	" 10	Sold, Nov. 2.	
665	-	Western.	1	601	" 11	Died, Oct. 16.	<i>B. coli</i> septicemia.
669	+	Native.	1	601	" 18	Killed, Feb. 13.	Normal.
680	+	"	1	678	Nov. 1	Sold, Dec. 10.	
681	-	Eastern.	3 (?)	?	" 2	Killed, Nov. 5.	<i>B. coli</i> septicemia.
685	-	Native.	3	?	" 9	Died, " 11.	" " "
687	+	Western.	1	679	" 9	Sold, Dec. 10.	
694	+	Eastern.	1	679	" 25	Died, Jan. 2.	No cultures. Poison (?).
697	-	"	3	679	" 29	Sold, Feb. 2.	
698	+	Native.	4	678	Dec. 6	" " 2.	
699	-	"	3	678	" 6	Died, Dec. 8.	<i>B. coli</i> septicemia.
715	+	"	1	712	Jan. 5	" Feb. 19.	Cultures sterile. Poison (?).
717	-	Western.	1	678	" 11	" Jan. 22.	<i>B. coli</i> septicemia.
716	-	Native.	3	712	" 11	Killed, Mar. 16.	Normal. Cultures sterile.
718	+	Western.	1	678	" 12	Sold, Feb. 2.	
757	+	Native.	3	678	" 23	Died, " 17.	Cultures sterile. Poison (?).
759	-	"	2	678	" 25	Killed, " 21.	Miscellaneous bacteri- emia.
893	+	"	1	712	Feb. 9	" Mar. 28.	Normal.
894	-	"	1	712	" 9	Died, " 13.	<i>B. coli</i> septicemia.
895	-	Eastern.	4	678	" 10	" " 13.	" " "
566	-	Native.	1	678	" 10	" " 12.	" " "

multiplication after death but, as will be seen farther on, these bacilli are present before natural death in abundance. Other organs were not cultured except in several cases certain joints which also yielded *Bacillus coli*.

The calf (No. 682) which died within 2 days and whose stomachs contained no food presented the same *Bacillus coli* septicemia.

No. 681 is of interest. On the 4th day of life it was too weak to get up and take its food. It would have presumably died during the night and it was therefore killed. The kidneys were firmer than normal and deeply congested. Cultures showed the presence of large numbers of *Bacillus coli* in the spleen, liver, and kidneys.

One calf (No. 717) died when 11 days old of a *Bacillus coli* septicemia. Cultures from one tarsal joint contained only *Bacillus coli*.

One calf (No. 759) which survived became lame. Several joints were involved. It was killed when 27 days old. There was a purulent fluid and a fibrin mold in one joint. The kidneys presented numerous whitish sclerotic foci. Cultures from the spleen remained sterile. Those from the kidneys and liver represented mixed infections, those from the joint exudate pure *Bacillus coli*. Of the two remaining calves, one was sold to the butcher in fine condition when 2 months and 3 days old. The other was killed when 2 months and 5 days old. The organs presented no abnormalities.

In Table I the cases are arranged according to the dates of birth. It shows that the calves deprived of colostrum and the controls were well balanced as to season.

#### DISCUSSION.

The data presented in the foregoing cases lead to certain definite inferences. The calf deprived of colostrum lacks something which permits intestinal bacteria to invade the body and multiply in the various organs. The rapidity and duration of this multiplication determine the fate of the calf. In most cases a rapidly fatal septicemia is the result. When the resistance is greater life may be prolonged or the animal survive indefinitely. The surviving animal may completely subdue the invading bacteria and develop into a normal calf or else localizations arise which involve, in the cases

here presented, the joints or the kidneys or both organs as in No. 759. The joint lesions are due to a fibrinous and purulent exudation. The bacteria present belong to *Bacillus coli*. The end-result of the localization in the kidneys is a fibrosis limited to the cortex with localized destruction of the secreting tissue. This occurs in foci of varying extent. The largest seen were about 1 cm. in diameter. This pathological condition, which was observed in 1917 associated with pneumonia due to *Bacillus actinoides*,<sup>8</sup> may now be considered as partly cleared up and it remains to study the early stages leading to fibrosis. The precise etiological factor may be *Bacillus coli* or some organism associated with it.

The bacteria isolated from the various cases and which were present in very large numbers in those that died and in fairly large numbers in those that were killed and cultured within 2 hours belong to that variety of *Bacillus coli* which is non-motile, indole-producing, and which fails to act on saccharose. This particular type of *Bacillus coli* has been under observation since 1917 and has been frequently isolated from the small intestines of calves dying in the first few days of life.

The experiments described are in a sense fundamental and many subsidiary questions are left unanswered. One of these is the effect of the ordinary milk of the different cows fed, whether protective and if so to what degree. In the table, the cow's milk fed is indicated by a number and it will be seen by consulting this that the source of the milk is not a determining factor in the experiment. Another question to be answered is whether it might not be possible by using extreme and unremitting care to raise most calves deprived of colostrum and how many of these would develop scours, joint lesions, omphalitis, or pneumonia in due time.

In general it may be concluded that the function of the colostrum is essentially protective against miscellaneous bacteria which are harmless later on when the protective functions of the calf have begun to operate and accumulate energy. There appears to be no function inherent in colostrum which controls development or growth or which is essential to the starting of the mechanism of digestion,

<sup>8</sup> Smith, T., *J. Exp. Med.*, 1921, xxxiii, 441.

since calves not having had colostrum appear to do as well as the others when the infection has been overcome.

The results obtained clear up much of the mystery surrounding the mortality and morbidity of very young calves. They explain why disease may appear when there is no evidence of introduction from without, and why the causes of disease of young calves up to 2 months old have been referred to the first days of life and to prenatal infection, especially where infectious abortion is prevalent. They moreover point out why so many different kinds of bacteria have been regarded as responsible for calf scours. Obviously the most invasive of the flora of any herd will dominate the bacteriology and different organisms will predominate in different territories unless the interchange of animals is very active, in which case the same flora will probably be found in many herds. The results also explain mixed infections, since the portal of entry from the intestinal tract is open.

These results furthermore show the inadequacy of all attempts at prevention based on keeping the invading bacteria away. These live in the normal cow, possibly some in the udder itself, and must be considered ubiquitous. They also demonstrate the futility of administering specific serum unless the dominating pathogenic organisms of the herd are known and used in its preparation.

It is not claimed as a result of these experiments that all colostrum-fed calves will resist the various forms of disease described, for we know that they prevail in spite of normal feeding at birth. There may be degrees of virulence in the intestinal, respiratory, and udder flora of cows against which normal feeding is quantitatively inadequate. It so happened that in the experiments reported no highly virulent types were present and therefore the dividing line between the calves protected by colostrum and those not so protected was unusually well defined.

#### CONCLUSIONS.

All of ten calves which were permitted to take colostrum after birth survived. Eight out of twelve calves which did not get colostrum died and one was killed moribund. One calf, killed on the 27th day, harbored miscellaneous bacteria in its organs. The kidneys



were sclerotic and one joint diseased. Of the remaining two calves, one had transitory joint troubles, the other rhinitis. One was sold and the other killed when 2 months old. In the latter the organs were normal and sterile.

*Notes on the Individual Calves.*

*Calf 566.*—Male, born Feb. 10, 1922, at 2.30 p.m., of a native cow in her second pregnancy. Calf removed from the dam immediately after birth and taken to the Department buildings at 4 p.m. There it was dried off by gentle friction with cloths. The umbilical cord was treated with bichloride of mercury and powdered boric acid. Fed  $1\frac{1}{2}$  lbs. milk (of Cow 678) from a bottle in evening.

Feb. 11. Calf fed three times today, drinking in all  $4\frac{1}{2}$  lbs. of milk. Temperature 39.0–39.5°C.

Feb. 12. Temperature 39.2°C. early. Calf drank first meal. Died about 11 a.m. Refrigerated at once until Feb. 13. The autopsy showed little of significance except the following.

The fourth stomach contained a milk curd the size of a small apple, some smaller clots, and milky fluid. Punctiform hemorrhages in leafy portion. Rectum deeply congested. Liver cells contain much fat. Extensive subendocardial extravasations of blood. Urine taken from bladder contains a trace of albumin. Both metatarsal joints contain some light yellowish fluid and soft mucoid flakes consisting largely of polynuclear leucocytes.

Cultures from spleen, liver, and kidneys are overgrown with a heavy glistening layer which in subsequent dilution cultures proves to be the saccharose-non-fermenting *B. coli*. One of several tubes inoculated with the exudate from the tarsal joint contains numerous colonies of the same organism.

*Calf 663.*—Born Oct. 4, 1921, at 11.50 a.m., of an eastern cow. First calf since introduction into herd. Calf not allowed to suckle the dam, and removed to Department unit at 1.35 p.m. Fed  $2\frac{1}{2}$  lbs. of milk from Cow 601 at 5.30 p.m. Abundant discharge of meconium during the night. Fed next morning. The discharges became softer and were yellowish in color.

Oct. 6. The calf was weak, unable to get up, and still scouring. Respirations shallow, about 60 per minute. Opaque, whitish, mucoid discharge from left nostril. Calf died at 11 a.m.

*Autopsy.*—Weight 67 lbs. Umbilical cord shrunken to a dried black tape-like body. Hemorrhagic discoloration of sheath and suspensory ligaments of umbilical artery stumps. Umbilical vein patent within abdomen to liver. Contents a normal blood clot. Beneath epicardium around base of heart, some hemorrhages. Hemorrhages within heart valves (auriculoventricular).

Digestive tract: Rumen normal. Fourth stomach contains white curds and some opalescent fluid. Leafy portion sprinkled with faded petechiæ. Pyloric portion and valve deeply congested. Uniform deep congestion of entire length

of small intestine. Bits of mucosa examined microscopically show complete injection of the network of capillaries in the villi. Large intestine congested but less so than the small. Liver shows considerable intracellular fat. The spleen is flabby, somewhat congested. Kidneys deeply congested. Urine taken from bladder is faintly clouded, yellow, slightly acid. Contains a trace of albumin and no sugar. Specific gravity 1.026.

Cultures from spleen and liver indicate large numbers of *B. coli* evidently pure. From the contents of a loop of the small intestine dilutions spread on agar show the same type of colonies. Those from a liver culture replated found to be colon bacilli non-motile, not fermenting saccharose.

*Calf 664.*—Born Oct. 10, 1921, at 5.20 p.m., first calf of a native cow, A 945. The dam had been vaccinated with a living culture of *B. abortus* before being bred. The parturition was normal and a guinea pig inoculated with material from a uterine swab was negative for *B. abortus*.

The calf remained with dam until 8.20 a.m. next day when it was removed to an isolation unit at the Department and fed milk from Cows 601 and 600. The temperature taken twice daily fluctuated between 38° and 39°C. The calf remained well and was sold Nov. 2.

*Calf 665.*—Born Oct. 11, 1921, at 2.50 p.m., of a midwestern cow introduced into the herd Sept. 27. Calf removed immediately after birth to a Department unit at 3 p.m. and fed milk from Cow 601.

Oct. 12. Calf drank 5 lbs. of milk in morning and 4 lbs. in evening. The temperature was 39° and 39.3°C.

Oct. 13. Calf drank 4 lbs. of milk morning and evening. Temperature 39° and 39.4°C.

Oct. 14. Calf drank 4 lbs. in morning. Feces soft, yellow, streaked with blood. Evening food withheld.

Oct. 15. Given 4 lbs. of milk. Temperature 39.8°C. Calf had a chill. Respirations 48; pulse 100. Feces soft with fetid odor. Discharge from both nostrils, mucous in character. Temperature, 5 p.m., 40.2°C. Calf drank 2 lbs. of milk. Temperature 39.6° at 9 p.m. Calf can stand up but unable to move legs freely.

Oct. 16. Temperature 38.6–39.1°C. during the day. Calf takes 1 lb. of milk, is very weak, unable to hold up head. Feces soft, streaked with blood. Legs cold. Dies at 11 p.m. and is placed in refrigerator.

The autopsy made early next morning. Weight of calf 88 lbs. The only noteworthy feature is an intense congestion of the medullary portion of kidneys. Urine from the bladder has a specific gravity of 1.011, yellow, cloudy, alkaline, albumin 0.2 per cent Esbach; sugar absent.

Cultures from spleen, liver, and kidneys show large numbers of colonies of non-motile bacilli like those from Calf 663. They ferment dextrose and lactose but not saccharose.

*Calf 669.*—Male, born Oct. 18, 1921, 1.20 p.m., first calf of a native cow. Remained with dam until 5 p.m. Then taken to an isolation unit at the Depart-

ment. The dam had been vaccinated same as dam of Calf 664. Calf was not fed in the evening. It refused milk next morning. In the evening it drank 2 lbs. The milk came from Cow 601.

The calf continued normal with temperature fluctuating between 37.5° and 38.5°C. until Nov. 5, when the daily taking was discontinued.

The calf was killed Feb. 14, 1922. It weighed 225 lbs. No lesions were found.

*Calf 680.*—Male, born during the night of Nov. 1 to 2, 1921, first-born of a native cow. The calf, which had suckled, was removed in the morning to an isolation unit at the Department and fed milk of Cow 678.

From Nov. 2 to 4, the stools were very liquid. Some diarrhea was again noticed on Nov. 21 and 22. The temperature fluctuated between 38° and 39°C. at this time. Otherwise the calf remained well and thrifty until sold Dec. 10.

*Calf 681.*—Male, born Nov. 2, 1921, 2 p.m., of a native cow. Probably the third or fourth calf. Calf kept from suckling the dam and brought over to a Department unit at 4.30 p.m. Fed 2 lbs. of milk.

Nov. 3. Fed 3 lbs. of milk in the morning. Large mass of feces passed with tendency to become liquid. Discharge from nose. Temperature 38.7–39.0°C.

Nov. 4. Takes 3 lbs. of milk. Discharge from nostrils more profuse. Calf grows weaker and unable to stand later in day. Temperature 39.2–39.7°C.

Nov. 5. Calf very weak, refuses food. Is unable to get up. In this case it was thought best to kill the calf to eliminate postmortem changes. Killed by stunning and cutting vessels of neck. Weight 73 lbs. The autopsy was negative except for the following.

The fourth stomach contained a mass of coagulated milk about 8 cm. in diameter. The mucosa of this organ and of the small and large intestines normal. The liver cells contain considerable fat. The kidneys are slightly enlarged, very firm to the touch, and deeply congested throughout. Urine from the bladder is yellowish, somewhat cloudy, slightly acid, specific gravity 1.030, albumin 0.15 per cent. Sections of the kidney show a complete injection of the entire capillary system. Those of spleen show numerous hemorrhages in the parenchyma.

Cultures were made from spleen, liver, and kidneys as follows: A bit of tissue about the size of a pea or small bean was transferred to an agar slant, rubbed over the surface, and deposited in the condensation water. A platinum loop dipped into this condensation water was rubbed over the slanted surface of a second tube. The numbers of colonies in the first tubes were countless. Those from the second tubes were 3 for the spleen, 15 for the liver, and 6 or 7 for the kidney. Dilutions from an intestinal loop planted in agar yielded the same kind of colonies; namely, the saccharose-non-fermenting *B. coli*.

*Calf 682.*—Born Nov. 2, 1921, before 6 a.m., of an eastern cow in her third pregnancy. This calf weak at birth remained so and was unable to take food. It grew weaker and was killed when about 33 hours old, Nov. 3, 2.30 p.m., to determine the presence or absence of *B. coli* septicemia.

The autopsy showed the absence of any food in the stomachs. These still contained the fetal fluids, viscid, bile-stained. The mucosa of nearly the entire

fourth stomach and pyloric valve was sprinkled over with minute, irregularly star-shaped hemorrhages, about 1 mm. apart. No surface hemorrhage. The small intestine nearly empty, normal. The lowest 24 inches of large intestine sprinkled with punctiform hemorrhages merging into a deep universal congestion in the rectum. The liver cells contained much fat. Other organs appear normal.

The cultures from spleen, liver, and kidney showed coalescing layers of growth in those in which bits of tissue had been placed. Those inoculated with a loop of condensation water from the preceding contained 6 or 7 colonies (spleen), 1 colony (kidney), and 6 or 7 colonies (liver). Dilutions of contents of an intestinal loop spread over agar showed the same type of colony. The bacilli were of the saccharose-non-fermenting type.

*Calf 685.*—Male, born Nov. 9, 1921, at 2 p.m., of a native cow in her third pregnancy. Calf removed from dam immediately after birth. At 3.10 p.m. placed with a cow which had calved 5 days ago. Calf began to suckle at 3.20 p.m. At 4 p.m. it was taken to a Department unit.

Nov. 10. Calf took 3 lbs. of milk early. Passed dark greenish masses of meconium. Feces tending to become liquid during the day. Temperature rose from 38.5°C. in morning to 39.6°C. in the late afternoon. Calf refused to take but a little milk late in the day, now very weak.

Nov. 11. Calf died at 5 a.m. From the autopsy record the following may be mentioned.

The umbilical vessels show only the usual amount of hemorrhagic discoloration. Rumens empty, normal. Fourth stomach normally distended with an opalescent, watery fluid and many small casein clumps. An area about 10 cm. in diameter of the leafy portion sprinkled with surface hemorrhages. Faded deeper hemorrhages in rest of leafy portion. In the small intestine there are well defined areas of deep congestion through the entire tube. There are linear congestions on crests of longitudinal folds of large intestine. Liver cells contain considerable fat. Spleen flabby. Some papillæ of kidneys congested. Heart and lungs negative.

Cultures from spleen, liver, and kidney show the same invasion of *B. coli* as in the preceding cases.

*Calf 687.*—Male, born Nov. 9, 1921, at 4.15 p.m. Remained with the dam until Nov. 10, 11.10 a.m., when it was removed to the Department animal house. The dam had been brought from Michigan in October. The calf refused to take milk (from Cow 679) the first evening, but drank next morning and thereafter. The temperature fluctuated between 38° and 39°C., rarely falling as low as 37.5°C. Nothing abnormal was observed. On Dec. 10 the calf was sold to the butcher.

*Calf 694.*—Born Nov. 25, 1921, at 1.30 p.m. Dam an eastern cow. Not known how many calves preceded this one. There was some difficulty in getting the calf to suckle the dam. At 4 p.m. it was induced to take colostrum from two quarters for about 10 minutes. At 4.30 p.m. it was transferred to the Department units. The subsequent feeding occasioned no special difficulties.

Up to Jan. 2, 1922, the temperature maximum and minimum were 39.8° and 37.5°C. Most of the morning and afternoon readings fluctuated between 38° and 39°C.

The calf was found dead unexpectedly at 7 a.m., Jan. 2. It had not been seen since 11 p.m., Jan. 1. It was at once placed in the refrigerator until Jan. 3. The autopsy presented the following points.

The mucosa of the digestive tract was abnormally pale. The fourth stomach contained a firm milk coagulum in which were enmeshed pieces of twine eaten by the calf from the straw bedding. There was more than the usual bile staining in the small and large intestines. The heart cavities contained soft dark clots and the endocardium was deeply suffused with blood coloring matter. The spleen was very flabby and of normal size. Some large bacilli (postmortem?) present. The liver was yellowish in color. There were a moderate amount of fat in the liver cells and some orange pigment. Bacteria not seen in films. The kidneys on section showed closely set, pale, linear streaks, passing vertically through cortex. In fresh scrapings the nuclei of the convoluted tubule epithelium contained each an irregular, refringent block or concretion. The thymus within the thorax was densely studded with hemorrhages up to 2 mm. in diameter. The cervical portion was free from them. Cultures were not made.

*Calf 697.*—Female, born Nov. 29, 1921, 2 p.m., of a native cow in her third pregnancy. The calf was unable to stand up for a time. At 2.45 p.m. it was transferred to the Department units and gently dried by rubbing with cloths. At 4 p.m. it was allowed to suckle another cow (No. 600) but fed poorly and obtained little.

Nov. 30. Temperature 38.5° and 39°C. Took 2½ lbs. of milk morning and evening. Voids large masses of meconium. The milk came from Cow 679. Dec. 1. Temperature 39° and 39.7°C. Drank 3 lbs. milk morning and evening. Mucopurulent discharge from nostrils. Dec. 2. Temperature 39.3° and 40.2°C. Food as yesterday. Dec. 3. Temperature 40°C. Discharge from nostrils abundant, thick. Feces normal. Dec. 4. Temperature 39.3° and 39°C. Food as before. The calf soon recovered from the rhinitis and gained weight normally. It was used in another experiment and sold to the butcher in fine condition Feb. 2, 1922. The inspector reported organs normal.

*Calf 698.*—Male, born Dec. 6, 1921, between 12 and 1, noon, fourth calf of a native cow. The calf was allowed to take the colostrum and then removed at 2.20 p.m. to the Department buildings.

The calf refused to drink next day until evening when some milk was slowly poured into its mouth. At 11 p.m. it drank about 12 ounces from a bottle. On the following day it began to take food in larger quantities. The temperature rose to 39.6°C. on Dec. 7. Thereafter it fluctuated between 38° and 39.5°C., falling to 37.4°C., Dec. 15. Temperature taking discontinued after Dec. 23. Calf sold to butcher Feb. 2, 1922. Inspector reported the organs normal.

*Calf 699.*—Male, born Dec. 6, 1921, at noon, of a native cow in her third pregnancy. Calf removed at once to Department buildings and dried off by rubbing with cloths. Fed about 2 lbs. of milk from Cow 678.

Dec. 7. Calf drank about 2½ lbs. of milk morning and evening. A large amount of feces was passed during the day, gradually assuming a liquid condition. Temperature 38.2° and 39.7°C. Dec. 8. Calf died at 8 a.m. At the autopsy the following appearances were noted.

The mucosa of pharynx and larynx cyanotic. A milk curd about 3 to 3½ inches in diameter in the fourth stomach and some milky fluid. Mucosa dark bluish red. The mucosa of small intestine deeply injected throughout. Microscopic examination shows complete injection of capillary system of villi. The large intestine similarly congested with intensification in the rectum. Bowels practically empty. Thoracic organs show nothing noteworthy. Liver cells contain considerable fat. The spleen is splashed with subcapsular hemorrhages. The kidneys are deeply congested throughout. Urine taken from the bladder is clear, yellow, acid. Specific gravity 1.025. A trace of albumin present.

Cultures from spleen, kidney, and liver show as heretofore the presence of large numbers of colon bacilli, not fermenting saccharose. The same type isolated from two segments of the small intestine. Other species not in evidence.

*Calf 715.*—Female, born Jan. 5, 1922, about 4 a.m., of a native cow in her first pregnancy. The calf was left with dam until 4 p.m. and then brought to the Department units.

The calf was fed milk from Cow 712 the next day and feeding continued three times daily. The temperature remained normal and the appetite good. From Jan. 18 on it was taking 12 lbs. of milk. Jan. 26. *B. bovissepticus* was introduced into one nostril and the reaction following was slight. It was found dead unexpectedly Feb. 19 at 5.30 a.m. when 45 days old. The watchman reported behavior of the calf similar to that of No. 757 before death. The calf was placed in the refrigerator until Feb. 20.

The only noteworthy changes observed at the autopsy were as follows: The fourth stomach contains milk clots mixed with twine picked out of bedding. The mucosa is partly digested. Extensive subendocardial hemorrhages in the left ventricle. All cavities contain soft dark clots. The spleen is very flabby and not enlarged. The liver cells contain large fat globules. The kidney cortex is regularly marked with grayish streaks. The intrathoracic portion of the thymus is permeated with hemorrhages 1 to 2 mm. in diameter.

Cultures of bits of tissue from liver, spleen, and kidneys in plain and blood agar slants and in fermentation tubes remain indefinitely sterile. Similarly, cultures from the heart's blood.

*Calf 716.*—Female, born Jan. 11, 1922, 1.15 p.m., of a native cow in her third pregnancy. Calf taken from cow and removed to the Department buildings, rubbed until nearly dry. Fed 1½ lbs. of milk from Cow 712 in evening from a nursing bottle.

Jan. 12 to 16. The calf takes milk regularly and is fed three times a day. The temperature is within the normal range. Jan. 17 to 18. Temperature 39.5°C. Evidence of joint involvement in left elbow and tarsal joints. Calf constipated. Jan. 19. Calf moves more easily about stall. Is taking 9 lbs. of milk daily in three doses. Feb. 1. Slight lameness in left fore leg and some weakness in hind limbs. Feb. 11. Swelling of left tarsal joint probably a distension of synovial sheaths. Feb. 28. Temperature has been normal to date. The joint troubles have practically disappeared. This calf was killed Mar. 16, when 2 months and 5 days old. There were no abnormal appearances of the organs and the cultures made as heretofore remained sterile.

*Calf 717.*—Male, born Jan. 11, 1922, at 4 p.m., of a midwestern cow. First calf since coming into this herd. The calf was removed at 5 p.m. to the Department buildings and dried off by gentle friction with cloths. Fed at 5.30 p.m. from a nursing bottle about 1 lb. of milk from Cow 678.

Jan. 12 to 19. Fed three times daily about 2 lbs. of milk each time. Jan. 20. Temperature up to 40.2°C. this morning. Calf is very weak but is taking its food as usual. Constipated. Temperature 41°C. at 8 p.m. Respirations short and irregular. Jan. 21. Calf took its food three times today. Is slightly better. Umbilicus slightly swollen and tender. Jan. 22. Calf too weak to get up and take its food. Dies at 10 a.m. Refrigerated at once until next day.

Jan. 23. Autopsy. Weight of calf 92 lbs. Umbilicus has a dry black tape still attached. Base slightly thickened and indurated. When tape removed, a circular area is exposed covered with a thin layer of pus and communicating with a closed diverticulum with purulent contents. No communication with umbilical vein, which is closed. The digestive tract normal with exception of some deeply congested patches of mucosa in ileum. Lungs slightly edematous and congested. Some small fibrin masses in pericardial sac and a few hemorrhages under epicardium. Liver, spleen, and kidneys softer than normal. Slight vascular injection of tissues within tarsal joints. Urine from the bladder contains only a trace of albumin. Specific gravity 1.012.

Cultures from spleen, liver, and kidneys show presence of large numbers of *B. coli*. Many colonies of the same bacilli in pure culture obtained from the fluid in one tarsal joint.

Sections of fixed and hardened tissue presented the following data. Spleen: Foci or colonies of *B. coli*-like rods scattered regularly through the section. Liver: One minute abscess in the section. Every liver cell contains one or more (fat) vacuoles. Each vacuole contains a central coccus-like body stained reddish (fat crystals). Kidney: Fibrin thrombi in small vessels of cortex. Occasional foci of polynuclear cells, interstitial hemorrhages, and *B. coli*-like rods filling capillaries.

*Calf 718.*—Male, born Jan. 12, 1922, at 7.45 a.m. Dam brought from Michigan Nov. 20, 1921. To make certain that the calf had received colostrum it was placed with the dam again at 11 a.m. and allowed to suckle the four quarters, in

all for 20 minutes. It was then brought to the Department buildings. The milk fed was from Cow 678. No difficulty was experienced in starting the artificial feeding. The maximum and minimum temperatures until Feb. 2 were 38.8° and 37.8°C. On this day it was sold to the butcher. Organs were reported normal by inspector.

*Calf 757.*—Male, born Jan. 23, 1922, at 9 a.m., of a native cow in her third pregnancy. The calf suckled the dam about 15 minutes before removal to the Department units. The cord was treated in the same way as that of Calf 893. The calf was fed three times daily with milk of Cow 678. The temperature and appetite continued normal. On Feb. 13, being in fine condition, it was used in another experiment, *B. bovissepticus* was introduced into a nostril. The reaction was slight.

On Feb. 17, when the calf was 22 days old and had been without abnormal symptoms thus far, it suddenly (1.55 p.m.) became very excited. It moved in a circle from left to right and lowed continually. The respirations were noisy, labored, the tongue protruded slightly, and there was more or less frothy mucus about the muzzle. The calf was forcibly restrained by being thrown and held. After a time the convulsive movements became less pronounced and the dyspnea more marked. It soon was unable to rise after being released and died 15 minutes after it had been discovered in this condition. This calf up to the time of the seizure had been in excellent condition and had even taken its milk early on the day of death as usual.

The autopsy showed nothing abnormal, except numerous small hemorrhages through the intrathoracic portion of the thymus and some minute hemorrhages under epicardium. The fourth stomach contained pieces of twine in the milk coagulum.

Cultures on plain and blood agar slants with bits of tissue from spleen, liver, and kidneys and with heart's blood, sealed, remained free from growth after 5 days incubation.

*Calf 759.*—Male, born of a native cow in her second pregnancy, Jan. 25, 1922, 3.20 p.m. Removed from the dam before suckling and taken to the Department buildings where it was dried off by gentle rubbing with cloths. The umbilical cord had been torn off close to the skin. The exposed area was washed with 0.1 per cent mercuric bichloride and dusted with powdered boric acid. The calf was very weak and scarcely able to stand up. Fed from bottle  $\frac{1}{4}$  lb. of milk from Cow 678. Fed again at 10.35 p.m.

Jan. 26. Fed three times today. Dry meconium being passed. Calf stronger. Jan. 27. Temperature 39°C. Takes food regularly. Soft yellow feces passed in large amounts, becoming liquid. Jan. 28. Temperature 39.1–39.2°C. Feces liquid. Jan. 29. Temperature 39–38.4°C. Lameness appears in right carpal and left tarsal joints. Calf quite weak. Feb. 4. Temperature has ranged close to 39°C. Some swelling of right carpal joint and stiffness in hind limbs.



Feb. 21. Calf has been improving and taking about 12 lbs. of milk daily. Killed today by stunning and cutting vessels of neck. Weight 87 lbs.

The autopsy showed the following abnormalities. In the right cephalic lobe of lungs some collapsed areas, each 4 to 5 mm. in diameter. Both kidneys spotted with white patches varying from mere specks to areas of a square centimeter. These areas correspond to the bases of solid foci reaching to medulla. A vertical section through these foci is either linear, square, fan-shaped, or oval. The involved tissue is white, smooth, glistening on section and quite firm. The distribution is irregular, not associated with any structures in the cortex. The urine taken from bladder is clear amber-colored, alkaline, specific gravity 1.020. A trace of albumin is present. The liver shows a distinct fatty zone on the periphery of the lobules.

In the right radiocarpal articulation a small quantity of an opaque fluid containing soft mucoid flakes together with a firm whitish fibrinous mold of a portion of the joint cavity, loose, and easily removed with forceps. The exudation and edema extend from the joint up the external aspect of the leg (radius) between the muscles for 3 to 4 inches. The joint exudate consists of polynuclear leucocytes.

Cultures were made with bits of tissue from spleen, liver, kidney, and the diseased joint. The spleen culture remained sterile. In the liver and kidney tubes several species of bacteria appeared, indicating a miscellaneous infection of the body. The joint cultures contained *B. coli*.

*Calf 893.*—Male, born Feb. 9, 1922, about 6 a.m. First-born of a native cow. Calf at first removed from dam as not having suckled, but owing to uncertainty in this respect, it was allowed to suckle dam at 11 a.m. for 20 minutes and then taken to the Department buildings. The umbilical cord was snipped off, leaving about 1 inch. This was dipped in 0.1 per cent mercuric chloride and covered with powdered boric acid. First meal taken the same evening was milk from Cow 712. There was no difficulty in feeding. The temperature was taken twice daily until March when the calf was used in another experiment. During this time, the maximum and the minimum temperatures were 39.4° and 37.7°C. The calf was killed Mar. 28. The only abnormality found was pigmentation of the mucosa of cecum, along the course of the larger vessels.

*Calf 894.*—Male, born Feb. 9, 1922, 6.30 a.m., of a native cow in her first pregnancy. The calf was removed from the dam but was not taken to the Department buildings until about noon. It was probably exposed and chilled in this interval. It was then gently rubbed with cloths and the umbilical cord treated as in earlier cases. Fed at noon and night from a bottle with milk from Cow 712. Feb. 10. Fed three times today. Temperature 38.8° and 39.2°C. Large amounts of dark greenish feces passed today. Feb. 11 to 12. Temperature range 38.8–39.4°. Tendency towards diarrhea. Feb. 13. Calf is very weak. Takes milk twice, but unable towards night to stand. Feces fluid. Dies at 10.30 p.m. Placed in refrigerator until next morning. Weight 73 lbs.

Autopsy negative except for petechiae in fourth stomach and a deep congestion of the mucosa of ileum. Tubes inoculated from spleen, liver, and kidneys show large numbers of colonies of *B. coli*.

*Calf 895*.—Male, born about 7 a.m., Feb. 10, 1922, of an eastern cow in her fourth pregnancy. Removed promptly from the dam and taken to the Department units at 10.20 a.m. where it was dried and umbilicus treated. The calf was fed at noon and evening with milk from Cow 678.

Feb. 11. Large amounts of relatively firm meconium discharged last night. Fed three times today. Temperature 38.8–39.7°C. Feb. 12. Fed as before. Calf growing weak and unable to stand later in day. Temperature 39.1–39.5°C. Feb. 13. Calf unable to stand up and drink. Nostrils filled with mucus. Temperature falling, 38.4–37.1°C. Died at 11 p.m. and refrigerated soon after.

Feb. 14. Autopsy presents the following points. The umbilical vein just beneath abdominal wall is distended with a normal clot about 2 cm. in diameter. No communication with exterior. Fourth stomach contains some curds and milky fluid. Many superficial hemorrhagic points in leafy portion. Rectum deeply congested. Some dried yellowish fecal matter in it, blood-stained. Both carpal joints contain several cubic centimeters of a turbid fluid with flakes made up of polynuclear leucocytes.

Interarticular surfaces of tibiotarsal joints deeply congested. Cultures from spleen, liver, and kidneys show coalescent layers of growth. Cultures from metatarsal joints, large numbers of isolated colonies. These and the growth from spleen were replated and found to be the same type of *B. coli*.