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CALF PARATYPHOID III.—THE TRANSMISSION OF ANTI-BODIES TO NEWLY-BORN CALVES.

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CONTENTS.

A. The Transmission of Anti-bodies from Immunized Pregnant Cows to their Calves.

Since the significance of colostrum as a carrier of anti-bodies from mother to new-born was demonstrated by Brieger and Ehrlich (1893) many workers have studied the problem and an extensive literature has accumulated on the subject. Famulener (1912) reported that the structure of the bovine placenta (epithelio-chorial) prevented the transmission of circulating immune bodies to the foetus *in utero* so that the serum of the new-born was entirely devoid of anti-bodies at the time of birth. Anti-bodies could be detected only after suckling. These observations were confirmed by Ratner, Jackson, and Gruehl (1927) Mason, Dalling and Gordon (1930), Schneider and Szathmary (1938, 1939), Alexander and Mason (1941), and several others (see McGirr, 1947). They produced evidence to show that the anti-bodies were absorbed by the intestine only during the first few days of the young animal's life and that the concentration of anti-bodies in the mammary secretion progressively fell as the secretion changed from colostrum to milk. Smith (1948) reported that globulins carrying the immune bodies in the colostrum readily passed through the intestine wall of the new-born to enter the bloodstream where they persisted for several weeks. Mason, Dalling and Gordon (1920) and Alexander and Mason (1941) showed that the progeny of mothers immunized against diseases like lamb dysentery and horsesickness were immune against these diseases for some time after birth, and that this immunity was obtained entirely through the colostrum.

Schneider and Szathmary (1938, 1939) reported that, depending on the structure of the placenta, immunity in new-born animals was acquired either through the placenta or the colostrum or both. On the basis of its histological structure the placenta was divided into four groups:—

I. Placenta epithelio-chorialis.

There is no intra-uterine transfer of immune bodies, but the immunity in the new-born is derived through the ingestion and absorption of globulins from the colostrum, mostly during the first suckle. Examples are cattle, horses, pigs and goats.

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II. Placenta syndesmo-chorialis.

In this group the anti-bodies, though transferred mostly through the colostrum, may be transmitted in very small, but detectable amounts, through the placenta, e.g. sheep.

III. Placenta endothelio-chorialis.

The anti-bodies are transmitted through both the placenta and the colostrum, e.g. dog.

IV. Placenta haemo-chorialis.

The anti-bodies are transferred exclusively by the intra-uterine route. But it is likely that the immunity conferred in this way can be augmented by the absorption of anti-bodies from the colostrum, e.g. human being, rabbit, mouse, rat, guinea-pig.

Little and Orcutt (1922), Quinlan (1923), and several other workers (see Huddleson, 1943) reported that the sera of new-born calves from cows infected with brucellosis were devoid of any Brucella agglutinins at the time of birth, but that these agglutinins might occur in high concentrations soon after a colostrum feed. Orcutt and Howe (1922) connected the appearance of agglutinins in the sera of new-born calves with the appearance of globulins in the blood, these globulins having been derived from the colostrum.

By salting-out methods Howe (1921) and Earle (1935) were able to demonstrate that the blood of new-born calves, foals, kids, lambs and pigs were free from euglobulin and pseudoglobulin I fractions at the time of birth, but that these proteins appeared in large amounts soon after a colostrum feed. By an electrophoretic study of the sera of new-born calves and foals, Jameson, Alvarez-Tostado and Sortor (1942) and Polson (1943) showed that the serum of these animals at birth was characterized by an extremely high albumin and α-globulin-concentration, by a comparatively low β-globulin content, and by the complete absence of γ-globulin. They found that the γ-fraction appeared soon after a colostrum feed and increased as nursing proceeded, whereas the amount of albumin and α-globulin decreased. According to Polson (personal communication) casein and serum globulins are the only proteins present in the colostrum of a cow, the γ-factor comprising about 75 per cent of the globulins, but no detectable albumin can be demonstrated in the colostrum.

In view of the importance of colostrum as a vehicle for conveying anti-bodies from immunized mothers to their new-born offspring it was thought that it might be useful to study the value of a colostral immunity in calves as a means of preventing losses against calf paratyphoid. The value of immune serum as a substitute for immune colostrum was also studied.

One hundred and sixty-one pregnant cows were inoculated with an aluminium-hydroxide adsorbed formalinized *S. dublin* vaccine about 8 to 10 weeks before calving, (see Tables I, II, III). Some of the cows received only two injections during a period of eight days, but others were given a third or boosting injection 30 days after the second. The concentration of the vaccine employed was approximately three times that of the routine vaccine used for calves, and the dose for each injection was 20 c.c. The agglutinin titre of the sera of these cows was determined before the first injection was made as well as a week after the second injection, and again at the time of calving. The titre of the sera of all the calves was tested 24 hours after birth and again at varying intervals afterwards

for a period of three months. In some of the calves, however, the titre was also tested before the first suckle. Before the first injection the cow's sera showed barely any "H" agglutinins, and no "O" agglutinins could be detected at a dilution of 1:10. The titre of the sera a week after the second injection is not given in the tables for the sake of convenience.

The agglutinin titre of the colostrum whey of 21 of the cows was obtained soon after calving and before the calves were allowed to suck, and again at various intervals subsequently. The agglutinin titre of the sera of the calves was noted before they received colostrum as well as 12 to 24 hours after a colostral feed, and at various periods during the following three months (see tables I, II and III).

It was found that the agglutinogenic response of pregnant cows to inoculations of *S. dublin* vaccine did not entirely agree with that observed in calves (see Henning 1952b, tables II, III and IV and compare with tables I, II and III, of this report). Although no serious difference in the production of "H" agglutinins could be observed between cows and very young calves, it was noticed that the "O" agglutinogenic response was much more marked in cows; whereas hardly any "O" agglutinins could be demonstrated in the sera of immunized calves, the "O" titre of several of the cows rose from 1:10 or less to 1:200 or more after immunization.

In Table I it is shown that large amounts of agglutinins were transferred from the immunized mother to the colostrum, and that the titre of the colostral whey was usually much higher than that of the maternal serum. Actually the "H" titre of the whey might be from two to 32 times as high as that of the cow's serum. It was not uncommon to find the "H" titre of the colostral whey as much as 1:25600 or more when it was barely 1:6400 or even less in the maternal serum. There was a much less marked rise in the "O" titre of the colostrum when compared with that of the maternal serum; and it was only in rare instances that the "O" titre of the colostral whey was more than twice that of the serum. The titre of the whey rapidly fell as the cow was milked or as the calf sucked, and hardly any agglutinins could be demonstrated ten days after calving.

Before a colostral feed the titre of the calf's serum, both "O" and "H", was usually less than 1:10 but within twelve hours after the calf was given colostrum from an immunized cow the "H" titre had generally risen to a level considerably higher than that of the cow's serum (tables II and III). For example the "H" titre of immunized cow No. 7772 was 1:800 at the time of calving, whereas the titre of its calf was 1:6400, 24 hours after the first suckle; and the "H" titre of cow No. 5830 was only 1:1600 compared with one of 1:51200 of its calf 24 hours after a colostral feed. The "O" titre of the calf's serum was either the same as that of the mother, or rarely a little higher, but it did not increase anything like the "H" titre. The titre of calf's serum remained more or less on the same level for about two or three weeks, and then gradually fell; but appreciable amounts of agglutinins persisted for at least two months after birth. There was, however, not always a definite correlation between the titres of the mother's and the calf's serum, and the transmission of agglutinins from mother to offspring was not always consistent. Sometimes the titre of the calf's serum might actually be less than that of the cow. Moreover, a cow which responded well to the inoculation, as was indicated by the development of a high agglutinin titre, might show a marked reduction in titre before calving if the parturition was delayed for some weeks after the last injection. Yet the titre of the calf's serum, after a colostral feed, might be higher than that of the cow at its highest level.

TABLE I.

The Transmission of Agglutinins from Immunized Cows to the Colostrum.

The agglutination titres of the sera of pregnant cows that were immunized with alum-precipitated *S. dublin* vaccine were recorded at the time of calving and the titre of the colostrum of these cows was noted up to 10 days after calving. The titre of the pre-colostrum of six immunized and one non-immunized cows was also noted. Three non-immunized cows were used as controls. Before immunization the "O" titre of all the cows was less than 1:10 and the "H" titre not more than 1:50 in any cow.

Number of Cow.	Titre of Cow's Serum at Time of Calving.		Colostral Whey at Time of Calving.		Titre of Whey 4 Days after Calving.		Titre of Whey 10 Days after Calving.		Titre of Precolostrum.	
	O.	H.	O.	H.	O.	H.	O.	H.	O.	H.
5926**	1,600	12,800	102,400	819,200	0	400	0	0	—	—
3474**	200	12,800	800	204,800	0	200	0	50	—	—
5573**	200	25,600	200	102,400	0	3,200	0	200	—	—
6513**	400	6,400	3,200	102,400	0	3,200	0	50	—	—
6896**	400	12,800	800	12,800	0	400	0	0	—	—
6817**	200	3,200	100	6,400	0	200	0	0	—	—
8002	100	1,600	400	12,800	0	200	0	0	—	—
83	200	800	800	25,600	—	—	—	—	—	—
937	200	12,800	400	3,200	—	—	—	—	—	—
1157	200	6,400	800	25,600	—	—	—	—	—	—
1175	100	3,200	50	1,600	—	—	—	—	800	800
1180	400	25,600	800	25,600	—	—	—	—	—	—
1186	200	800	200	3,200	—	—	—	—	0	800
1303	100	3,200	200	12,800	—	—	—	—	400	25,600
1353	200	800	800	3,200	—	—	—	—	—	—
1356	200	400	800	3,200	—	—	—	—	800	1,600
7811	100	1,600	400	25,600	—	—	—	—	800	6,400
7880	100	6,400	400	25,600	—	—	—	—	—	—
7881	50	12,800	800	51,200	—	—	—	—	800	12,800
9033	200	800	400	6,400	—	—	—	—	—	—
9037	200	1,600	200	12,800	—	—	—	—	—	—
9048*	0	0	0	50	—	—	—	—	—	—
9051*	0	100	0	50	—	—	—	—	0	100
7528*	25	800	0	400	—	—	—	—	—	—

* Cows not immunized.

** The titre of the sera of the calves is given in Table II.

TABLE II.

The Transmission of Agglutinins from Immunized Cows to Calves.

Pregnant cows were inoculated twice with alum-precipitated *S. dublin* vaccine and the transmission of agglutinins from the cows to the calves through the colostrum was noted. The agglutinin titres of the cows' sera were recorded at the time of calving, and the gradual fall of the titre of the calves' sera was noted. Before immunization the "O" titre of the cows was less than 1:10 and the "H" titre was not more than 1:50 in any cow. Before the first suckle both the "O" and "H" titres of the calves were less than 1:10.

Number of Cow.	Titre of Cow's Serum at Time of Calving.		Titre of Calf's Serum ± 24 Hours after first Suckle.		Titre of Calf's Serum ± 8 Days after Birth.		Titre of Calf's Serum ± 15 Days after Birth.		Titre of Calf's Serum ± 40 Days after Birth.		Titre of Calf's Serum ± 60 Days after Birth.	
	O.	H.	O.	H.	O.	H.	O.	H.	O.	H.	O.	H.
5816	50	200	50	800	25	800	—	—	0	200	0	200
5873	50	1,600	100	6,400	25	3,200	—	—	0	800	0	800
7492	25	400	50	3,200	—	—	0	3,200	0	400	0	400
7534	25	3,200	25	6,400	—	—	0	3,200	0	200	0	200
7542	0	1,600	50	1,600	25	400	—	—	0	400	25	800
7772	25	800	50	6,400	25	1,600	25	800	0	800	—	—
7810	25	200	25	400	25	400	0	400	0	200	—	—
8524	25	800	25	800	25	1,600	—	—	0	400	—	—
8537	25	100	50	800	—	—	25	400	0	400	—	—
5830	50	1,600	100	51,200	100	51,200	50	3,200	25	3,200	25	1,600
7666	0	400	50	1,600	50	1,800	50	800	50	400	—	—
7868	25	1,600	100	51,200	50	6,400	50	3,200	0	1,600	0	800
8052	100	6,400	50	51,200	100	6,400	25	1,600	0	1,600	—	—
5870	—	—	50	12,800	0	12,800	0	25,600	0	3,200	—	—
6804	25	3,200	100	1,600	25	1,600	25	3,200	0	1,600	—	—
8074	100	1,600	200	1,600	25	800	0	400	25	200	—	—
6893	50	51,200	0	12,800	0	12,800	0	6,400	—	—	—	—
6641	50	51,200	100	51,200	0	6,400	25	12,800	—	—	—	—
6845	25	25,600	50	51,200	—	—	0	51,200	25	25,600	—	—
8088	50	51,200	25	51,200	25	12,800	100	1,600	0	6,400	—	—
6836	—	—	100	51,200	—	—	25	51,200	0	6,400	—	—
6821	25	1,600	100	51,200	0	6,400	25	12,800	25	1,600	—	—
5849	100	200	100	51,200	—	—	50	25,600	25	800	—	—
5926	1,600	12,800	800	1,600	50	800	—	—	0	400	0	200
3474	200	12,800	0	800	0	400	—	—	0	200	0	0
5573	200	25,600	800	25,600	0	12,800	—	—	0	3,200	0	3,200
6513	400	6,400	200	12,800	100	12,800	—	—	100	12,800	—	—
6896	400	12,800	800	25,600	200	12,800	—	—	100	12,800	0	3,200
6817	200	3,200	0	12,800	0	800	—	—	0	400	0	800

COMMENTS.—These results show that the agglutinin titre of the calf, when tested approximately 24 hours after a colostral feed, may be several times higher than that of its mother at the time of calving, and that appreciable amounts of agglutinin persist in the calf's serum for at least two months after birth.

TABLE II (*Continued*).

Number of Cow.	Titre of Cow's Serum at Time of Calving.		Titre of Calf's Serum ± 24 Hours after first Suckle.		Titre of Calf's Serum ± 8 Days after Birth.		Titre of Calf's Serum ± 15 Days after Birth.	
	O.	H.	O.	H.	O.	H.	O.	H.
3.....	0	800	0	6,400	0	800	0	400
4.....	0	3,200	0	1,200	0	800	0	400
5.....	0	25,600	25	25,600	0	6,400	—	—
7.....	50	25,600	200	204,800	50	51,200	50	204,800
9.....	25	800	25	3,200	0	1,600	0	800
10.....	0	800	0	6,400	0	1,600	0	800
11.....	25	400	0	3,200	0	3,200	0	800
12.....	0	3,200	50	12,800	50	12,800	0	3,200
13.....	50	51,200	50	204,800	50	12,800	25	1,600
14.....	25	3,200	100	25,600	50	25,600	0	1,600
15.....	25	3,200	0	800	0	800	0	800
16.....	0	800	25	3,200	25	1,600	0	800
17.....	0	400	25	25,600	25	6,400	0	6,400
19.....	50	800	100	12,800	25	3,200	0	3,200
20.....	25	1,600	25	25,600	0	3,200	0	400
22.....	0	400	0	6,400	0	12,800	0	800
23.....	0	1,600	0	3,200	0	1,600	0	800
24.....	0	1,600	0	6,400	—	—	0	800
	0	400	0	800	0	400	0	400
26.....	25	1,600	25	12,800	0	800	0	200
27.....	25	12,800	50	204,800	50	51,200	25	3,200
28.....	25	1,600	50	6,400	0	3,200	0	1,600
29.....	0	800	25	1,600	0	800	0	800
30.....	25	3,200	0	3,200	0	1,600	0	100
31.....	0	800	25	1,600	25	1,600	0	800
32.....	0	400	25	3,200	25	1,600	0	400
33.....	50	51,200	500	204,800	50	61,200	25	3,200
	0	25,600	50	1,600	25	800	0	800
35.....	0	400	0	6,400	0	3,200	0	800
36.....	25	1,600	50	12,800	0	6,400	0	1,600
38.....	0	400	0	12,800	0	1,600	0	800
39.....	25	400	50	3,200	25	800	0	400
41.....	25	800	100	6,400	50	3,200	—	—
42.....	25	3,200	25	6,400	0	1,600	0	800
43.....	0	400	0	12,800	0	6,400	0	3,200
44.....	0	12,800	0	25,600	0	12,800	0	1,600
45.....	25	12,800	50	51,200	0	12,800	0	3,200
46.....	0	800	25	6,400	0	1,600	0	800
47.....	0	1,600	0	400	0	100	0	200
48.....	25	3,200	25	6,400	25	6,400	0	800
49.....	0	6,400	100	6,400	0	1,600	0	200

COMMENTS.—These results show that the agglutinin titre of the calf, when tested approximately 24 hours after a colostral feed, may be several times higher than that of its mother at the time of calving, and that appreciable amounts of agglutinin persist in the calf's serum for at least two months after birth.

The Protection afforded by a Colostral Immunity.

Fourteen calves from immunized cows were used for the test. The "H" titre of these calves, 24 hours after the first suckle, varied from 1:6400 to 1:51200. The "O" titre was insignificant (1:10 or less). The titre of the calf's serum was generally much higher than that of its mother.

Eight days after birth the immunity of these calves was challenged by means of fresh milk cultures of *S. dublin* (see Henning, 1952, b). Although a definite rise in temperature could be detected in all the calves from two to six days after the infection, there was very little disturbance in their general health, and the mild temperature reaction seldom persisted for more than two or three days. Not one of the calves showed any serious discomfort, and everyone made an uneventful recovery. In two of the calves *S. dublin* was recovered from the faeces from three to four weeks after infection, but all faeces cultures were negative when the calves were discharged at the age of eight weeks.

There seems to be very little doubt that the reactions shown by these calves to oral infection were far milder than those exhibited by the calves in a previous study (Henning, 1952 b). Not one of the 14 calves in this test succumbed to the challenge infection, whereas the majority of the untreated calves in the previous report died from seven to fourteen days after oral infection. It may be reasonable to suggest, therefore, that this resistance should be ascribed to the presence of anti-bodies obtained from their immunized mothers through the colostrum. In view of these results the routine immunization of pregnant cows as an alternative method of combating paratyphoid in young calves is recommended.

B. The Transmission of Anti-bodies to Newly-born Calves by means of Anti-serum given per os.

Adult cows were hyper-immunized, and when a serum of a suitable titre was obtained the cows were bled and their sera harvested. Only sera with an "H" agglutinin titre of not less than 1:102400 were employed. As has been reported elsewhere (Henning 1952 b), sera of a very high agglutinin titre were usually obtained when immunized cows were given a boosting injection of vaccine approximately 30 days after the previous inoculation.

The calves were given the immune serum either before or after they had received colostrum or normal milk from non-immunized cows. One litre of serum was administered by means of a stomach tube on an empty stomach and the agglutinin titre of the calf's serum was tested at various periods.

Group I.—Calves were given immune serum very soon after birth and before they had received colostrum or milk.

Calf No. 1 (*Griet*).

Titre of immune serum given, O = 0; H = 102,400.

Titre of calf's serum before it received colostrum of immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it received immune serum, O = 0; H 1,600.

Titre of calf's serum 24 hours after it received immune serum, O = 0; H = 1,600.

Titre of calf's serum 32 days after it received immune serum, O = 0; H = 400.

Titre of calf's serum 57 days after it received immune serum, O = 0; H = 200.

Calf No. 12.

Titre of immune serum given, O = 0; H = 204,800.

Titre of calf's serum before receiving immune serum, O = 0; H = 400.

Titre of calf's serum 6 hours after receiving immune serum, O = 0; H = 3,200.

Titre of calf's serum 24 hours after receiving immune serum, O = 0; H = 6,400.

Titre of calf's serum 7 days after receiving immune serum, O = 0; H = 6400.

Titre of calf's serum 14 days after receiving immune serum, O = 0; H = 6,400.

Titre of calf's serum 30 days after receiving immune serum, O = 0; H = 3,200.

The calf was allowed to drink colostrum and milk from mother twelve hours after it had received immune serum.

Calf No. 63.

Titre of immune serum given, O = 0; H = 204,800.

Titre of calf's serum before receiving colostrum or immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after receiving immune serum, O = 0; H = 25,600.

Titre of calf's serum 24 hours after receiving immune serum, O = 0; H = 12,800.

Titre of calf's serum 7 days after receiving immune serum, O = 0; H = 25,600.

Titre of calf's serum 14 days after receiving immune serum, O = 0; H = 12,800.

Titre of calf's serum 30 days after receiving immune serum, O = 0; H = 6,400.

Titre of calf's serum 90 days after receiving immune serum, O = 0; H = 400.

Twelve hours after it was given immune serum the calf was allowed to suck colostrum or milk from its dam.

Calf No. 5282.

Titre of immune serum given, O = 0; H = 204,800.

Titre of calf's serum before receiving colostrum or immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after receiving immune serum, O = 0; H = 1,600.

Titre of calf's serum 24 hours after receiving immune serum, O = 0; H = 3,200.

Titre of calf's serum 7 days after receiving immune serum, O = 0; H = 1,600.

Titre of calf's serum 14 days after receiving immune serum, O = 0; H = 3,200.

Titre of calf's serum 30 days after receiving immune serum, O = 0; H = 1,600.

Titre of calf's serum 42 days after receiving immune serum, O = 0; H = 800.

The calf was allowed to drink colostrum and milk from its mother twelve hours after it had received the immune serum.

Calf No. 14.

Titre of immune serum given, O = 0; H = 102,400.

Titre of calf's serum before it received milk or immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it received immune serum, O = 0; H = 3,200.

Titre of calf's serum 24 hours after it received immune serum, O = 0; H = 3,200.

Titre of calf's serum 7 days after it received immune serum, O = 0; H = 3,200.

Titre of calf's serum 14 days after it received immune serum, O = 0; H = 1,600.

Twelve hours after receiving the immune serum calf 14 was given pure milk but no colostrum at any time.

Calf 64.

Titre of immune serum given, O = 0; H = 204,800.

Titre of calf's serum before it received milk or immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it received immune serum, O = 0; H = 51,200.

Titre of calf's serum 24 hours after it received immune serum, O = 0; H = 51,200.

Titre of calf's serum 7 days after it received immune serum, O = 0; H = 12,800.

Titre of calf's serum 14 days after it received immune serum, O = 0; H = 12,800.

Titre of calf's serum 30 days after it received immune serum, O = 0; H = 6,400.

Titre of calf's serum 80 days after it received immune serum, O = 0; H = 400.

Twelve hours after receiving immune serum calf 64 was given pure milk, but it did not receive colostrum at any time.

Calf No. 66.

Titre of immune serum given, O = 0; H = 102,400.

Titre of calf's serum before it received milk or immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it received immune serum, O = 0; H = 6,400.

Titre of calf's serum 24 hours after it received immune serum, O = 0; H = 6,400.

Titre of calf's serum 7 days after it received immune serum, O = 0; H = 6,400.

Titre of calf's serum 30 days after it received immune serum, O = 0; H = 3,200.

Titre of calf's serum 64 days after it received immune serum, O = 0; H = 800.

Twelve hours after receiving immune serum calf No. 66 was given pure milk, but no colostrum was given at any time.

Remarks.—These results show that newly-born calves can absorb a large amount of agglutinins from immune serum administered by the mouth before they are allowed to drink colostrum or milk. The feeding of colostrum from immune cows 12 hours after the administration of immune serum had no effect on the titre of the calves' serum.

Group II.—Calves were allowed to drink colostrum or milk from non-immunized cows before they were given immune serum.

The "H" titre of the immune serum used varied from approximately 102,400 to 204,800. The "O" titre was very low.

Calf No. 602.

The calf was allowed to remain with its unimmunized dam and suck colostrum for approximately twelve hours after birth. It was then removed from its dam for about 12 hours before it was given immune serum.

Titre of calf's serum before it received immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it had received immune serum, O = 0; H = 800.

Titre of calf's serum 24 hours after it had received immune serum, O = 0; H = 1,600.

Titre of calf's serum 7 days after it had received immune serum, O = 0; H = 400.

Calf No. 475.

The calf was allowed to remain with its un-immunized dam and suck colostrum for 36 hours before it was given immune serum.

Titre of calf's serum before it received immune serum, O = 0; H = 0.

Titre of calf's serum 24 hours after it had received immune serum, O = 0; H = 400.

Titre of calf's serum 48 hours after it had received immune serum, O = 0; H = 400.

Calf No. 5302.

Received three meals of two pints of milk each during a period of 24 hours. It was then starved for twelve hours before it was given immune serum. The calf was not allowed any colostrum at all.

Titre of calf's serum before it received immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it had received immune serum, O = 0; H = 1,600.

Titre of calf's serum 24 hours after it had recevied immune serum, O = 0; H = 1,600.

Titre of calf's serum 48 hours after it had received immune serum, O = 0; H = 3,200.

Titre of calf's serum 7 days after it had received immune serum, O = 0; H = 6,400.

Titre of calf's serum 30 days after it had received immune serum, O = 0; H = 400.

Titre of calf's serum 47 days after it had received immune serum, O = 0; H = 200.

Calf No. 5311.

Was removed from its mother before it could partake of any colostrum. It was then fed for two days on ordinary milk. Titre of calf's serum before it received the immune serum O = 0; H = 0. Serum taken 24 hours later showed no trace of "O" or "H" agglutinins. Repeated tests performed up to 30 days after birth did not reveal the presence of any agglutinins.

Calf No. 5318.

Was removed from its mother before it could suck and was fed twice on pure milk during a period of twelve hours. After twelve hours starvation the calf was given immune serum.

Titre of calf's serum before it received immune serum, O = 0; H = 0.

Titre of calf's serum 6 hours after it had received immune serum, O = 0; H = 200.

Titre of calf's serum 24 hours after it had received immune serum, O = 0; H = 200.

Titre of calf's serum 48 hours after it had received immune serum, O = 0; H = 100.

Titre of calf's serum 7 days after it had received immune serum, O = 0; H = 100.

Titre of calf's serum 30 days after it had received immune serum, O = 0; H = 50.

Twenty-four hours after the calf had received the immune serum it was given one litre of colostrum from an immune cow. The titre of colostrum whey was O = 400; H = 1,000,000. No increase in the titre of the calf's serum could be effected by the immune colostrum and the agglutinin titre remained low.

Calf No. 23419.

Was removed from it mother and was given two feeds of two pints of milk during a period of twelve hours. The calf was then starved for twelve hours and given the immune colostrum.

Titre of calf's serum before it received colostrum, O = 0; H = 0.

Titre of calf's serum 6 hours after it had received colostrum, O = 0; H = 100.

Titre of calf's serum 24 hours after it had received colostrum, O = 0; H = 100.

Titre of calf's serum 30 days after it had received colostrum, O = 0; H = 50.

Remarks.

These results show that newly-born calves can absorb large amounts of agglutinins from immune serum administered by the mouth before they are allowed a colostral or milk feed. These agglutinins persisted in the calves' sera for some time. In most cases the agglutinin titre remained fairly high for at least 30 days and persisted at a significant level for another month or longer.

When the calves received a colostral or a milk feed before they were given immune serum by the mouth their power to absorb agglutinins via the alimentary canal was markedly reduced. Although perceptible amounts of agglutinins were detectable in some of the calves' sera, the agglutinin titre of these was generally very low when compared with that of the calves that were not allowed a feed before they were given immune serum. Very high titre immune colostrum administered 12 to 24 hours after the immune serum could not increase the agglutinin titre of the calves' sera.

It seems obvious, therefore, that for the transmission of immune bodies by means of immune serum to newly-born calves via the alimentary canal, the best results will be obtained if the serum is administered before the calves are given any milk or colostrum by the mouth.

It should be pointed out, however, that although newly-born calves have the power to absorb large amounts of agglutinin from immune serum administered by the mouth before the first feed they can apparently obtain considerably more agglutinins from immune colostrum than from immune serum. Although immune serum may, therefore, be substituted for immune colostrum when immune colostrum is not available, it is probably a less effective protective agent.

C. The Inoculation of Calves of Immunized Cows with *S. Dublin* Vaccine.

The calves of 66 of the immunized pregnant cows were inoculated with routine *S. dublin* vaccine at variable periods after birth (table III). Large amounts of agglutinins were demonstrated in the sera of these calves 24 hours after birth

and before the first inoculation was made. Some of the calves received their first inoculation a day or two after birth and others were not inoculated until they were one or two weeks old. Most of the calves received two inoculations. The interval between the injections was about a week. Some calves, however, received a third or boosting inoculation approximately 30 days after a previous injection.

No appreciable agglutinogenic response could be observed after any of these inoculations, and no difference in the agglutinin titre of the inoculated and uninoculated calves of immunized dams could be found (compare tables II and III). Not even by means of a boosting injection given 30 days after the previous injection was it possible to stimulate the production of agglutinins. The agglutinogenic response to the vaccine was apparently completely blocked out by the colostral immunity. It was not determined how long this blockage persisted, but as agglutinins were demonstrable in the sera of the calves for two or three months after birth an immunity response was apparently not likely to occur until the calves were at least two months old.

Summary and Conclusions.

1. In a study of the transmission of anti-bodies from immunized pregnant cows to the colostrum and to their progeny it was noticed that the agglutinin titre of the colostral whey and of the calf's serum might be several times that of the dam. At the time of birth hardly any agglutinins, or no agglutinins at all, could be detected in the calf's serum, but the titre suddenly rose to this high level within 24 hours after the first suckle. The calf's titre remained high for two weeks or more, and then gradually declined; but it remained at a significant level for about three months.

2. When newly-born calves from immunized or unimmunized mothers were fed on hyperimmune serum before the first suckle large amounts of agglutinins could be detected in their sera twelve hours later. These agglutinins persisted, though in progressively decreasing titre, for at least three months.

3. When the calves from immunized cows were inoculated with *S. dublin* vaccine one, two or three weeks after a colostral feed, no rise could be effected in the agglutinin titre and no difference could be detected in the titre whether the calves had been inoculated or not. The immunity was apparently completely blocked by the anti-bodies absorbed from the colostrum.

4. When the colostral immunity was challenged with virulent milk cultures given by the mouth the calves exhibited a fair degree of resistance, and it was extremely difficult to produce typical symptoms of paratyphoid in them. It is believed that this immunity is sufficient to protect young calves against natural exposure to paratyphoid. The immunization of pregnant cows as a means of protecting new-born calves against paratyphoid is, therefore, recommended as an additional method of combating the disease. But as hyperimmune sera, when given before the first suckle, can also transmit anti-bodies to new-born calves the use of immune sera is advised in cases where immune colostrum is not available.

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TABLE III.

The Inoculation of the Calves of Immunized Cows with S. dublin *Vaccine.*

Pregnant cows were immunized with *S. dublin* vaccine and the agglutinin titre of their sera was determined at the time of calving. The agglutinin titre of the calves' sera was recorded at the time of birth and at intervals up to 60 days after birth. At approximately 7 and 15 days after birth the calves were inoculated with routine *S. dublin* vaccine. Before the first inoculation the "H" titre of the cows was less than 1:50 and the "O" less than 1:10.

Number of Cow.	Titre of Cow's Serum at Time of Calving.		Number of Calf.	Titre of Calf's Serum ± 24 Hours after first Suckle.		Titre of Calf's Serum ± 8 Days after Birth.		Titre of Calf's Serum ± 15 Days after Birth.		Titre of Calf's Serum ± 21 Days after Birth.		Titre of Calf's Serum ± 40 Days after Birth.		Titre of Calf's Serum ± 60 Days after Birth.	
	O.	H.		O.	H.	O.	H.	O.	H.	O.	H.	O.	H.	O.	H.
7507	0	800	868	50	204,800	—	—	0	3,200	0	1,600	0	800	0	400
7512	50	6,400	866*	200	51,200	—	—	25	6,400	—	—	0	400	0	400
7519	25	400	913*	25	800	25	400	—	—	0	400	0	200	0	200
7557	50	25,600	872	50	51,200	—	—	0	51,200	0	6,400	0	3,200	0	800
7576	50	800	935	50	102,400	25	51,200	—	—	0	3,200	0	3,200	0	800
7784	0	400	947	50	1,600	25	3,200	—	3,200	0	1,600	0	1,600	0	800
7795	25	400	985*	50	1,600	25	1,600	—	—	25	400	0	400	—	—
7800	0	400	910	50	3,200	—	—	0	1,600	0	800	0	400	0	400
7811	0	800	939	50	12,800	0	12,800	0	3,200	25	6,400	0	3,200	0	3,200
7872	0	400	1011*	25	800	25	800	25	400	—	—	0	400	0	400
7875	25	400	914	100	12,800	—	—	0	3,200	25	3,200	—	—	25	1,600
7881	0	1,600	934	0	1,600	50	51,800	50	3,200	25	3,200	—	—	—	—
7894	25	1,600	937	200	51,200	50	3,200	50	3,200	25	3,200	25	1,600	—	—
8042	100	800	911	100	3,200	—	—	50	3,200	0	400	0	200	0	200
8558	25	6,400	820	50	6,400	25	1,600	0	800	0	800	0	400	0	400
8574	25	500	980*	100	12,800	50	6,400	—	—	25	3,200	25	3,600	—	—
5940	0	200	949	50	800	25	400	—	—	0	800	0	400	0	400
6621	25	1,600	940	25	3,200	0	800	0	800	25	800	0	800	0	400
7504	50	1,600	909	50	6,400	25	1,600	25	800	0	800	0	400	—	—
7506	25	12,800	871	50	25,600	25	6,400	25	6,400	0	800	0	400	0	800
7509	50	6,400	936	25	1,600	0	1,600	0	400	25	800	0	400	0	200
7528	50	25,600	867	100	6,400	50	6,400	0	3,200	0	800	0	400	0	200
7544	0	200	984*	25	800	25	800	—	—	—	—	—	—	—	—
7771	100	51,200	952	50	25,600	50	25,600	50	3,200	25	3,200	0	1,600	0	1,600
7808	50	1,600	908	200	51,200	50	3,200	25	3,200	25	800	25	1,600	25	800
7848	0	200	932	25	800	0	1,600	0	400	0	400	0	400	0	400
7850	25	800	938	100	6,400	50	1,600	25	1,600	25	1,600	0	800	0	800
7858	100	1,600	946	100	51,200	25	1,600	25	1,600	0	1,600	0	3,200	0	800
7861	0	1,600	874	50	6,400	25	3,200	25	3,200	0	800	0	800	0	1,600
7866	25	200	950*	25	800	25	800	0	800	0	200	0	400	—	—
8126	25	3,200	941*	50	12,800	25	12,800	25	12,800	0	1,600	0	400	0	200
8394	0	1,600	948*	0	3,200	0	3,200	0	3,200	0	1,600	0	1,600	—	—
6933	25	51,200	355	25	3,200	—	—	0	3,200	—	—	0	800	0	800

* Calves received only one injection, all the others received two injections.

TABLE III (*Continued*).

Number of Cow.	Titre of Cow's Serum at Time of Calving.		Number of Calf.	Titre of Calf's Serum ± 24 Hours after first Suckle.		Titre of Calf's Serum ± 8 Days after Birth.		Titre of Calf's Serum ± 15 Days after Birth.		Titre of Calf's Serum ± 21 Days after Birth.		Titre of Calf's Serum ± 40 Days after Birth.		Titre of Calf's Serum ± 60 Days after Birth.	
	O.	H.		O.	H.	O.	H.	O.	H.	O.	H.	O.	H.	O.	H.
8103	0	400	358	50	51,200	—	—	0	6,400	—	—	0	6,400	0	6,400
6674	100	12,800	359	200	25,600	—	—	25	6,400	—	—	25	6,400	25	3,200
5834	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
6730	25	800	328	25	1,600	—	—	25	800	—	—	0	800	0	400
6604	50	800	384	25	800	—	—	0	400	—	—	0	400	0	400
6758	0	3,200	417	0	12,800	—	—	0	6,400	—	—	0	6,400	0	6,400
6996	100	6,400	437	50	12,800	—	—	0	6,400	—	—	0	800	0	400
6983	25	25,600	436	0	6,400	—	—	0	6,400	—	—	0	400	0	800
8116	50	6,400	441	0	12,800	—	—	0	6,400	—	—	0	800	0	800
6626	50	12,800	425*	0	6,400	—	—	0	6,400	—	—	0	3,200	0	3,200
5896	25	3,200	445	0	12,800	—	—	0	6,400	—	—	0	1,600	0	800
6778	0	6,400	350	200	1,600	0	800	0	800	0	800	—	—	0	100
8174	100	400	367	0	800	0	800	0	400	0	400	—	—	0	400
5934	—	—	520	200	51,200	50	25,800	25	3,200	0	25,600	—	—	0	1,600
8163	50	1,600	374	100	25,600	25	12,800	25	3,200	0	3,200	—	—	0	25,600
6726	25	51,200	390	0	51,200	0	100	0	100	0	100	—	—	0	0
8104	100	25,600	398	200	51,200	200	12,800	25	25,600	0	6,400	—	—	0	6,400
6523	0	400	416	50	25,600	25	6,400	0	6,400	0	6,400	—	—	0	3,200
6722	25	6,400	428	25	6,400	0	3,200	0	6,400	0	12,800	—	—	0	400
5835	—	—	432	25	25,600	0	6,400	0	3,200	0	400	—	—	0	800
6745	25	25,600	435	25	51,200	0	3,200	0	3,200	0	100	—	—	0	400
8181	50	51,200	443	0	12,800	0	6,400	0	3,200	0	1,600	—	—	0	1,600
6520	50	6,400	444	25	51,200	0	12,800	0	12,800	0	3,200	—	—	0	3,200
8171	100	6,400	357	50	12,800	50	6,400	25	800	50	800	—	—	0	800
5893	25	1,600	366	50	3,200	50	3,200	25	3,200	0	800	—	—	0	400
6773	50	3,200	369	50	3,200	25	6,400	0	6,400	0	800	—	—	0	800
8142	50	51,200	376	0	3,200	0	1,600	0	400	0	800	—	—	0	800
5781	50	800	389	25	3,200	0	800	0	800	0	400	—	—	0	400
8112	25	1,600	415	50	12,800	25	6,400	0	25,600	0	3,200	—	—	0	800
6925	25	12,800	420	50	12,800	0	12,800	0	6,400	0	6,400	—	—	0	800
6921	25	3,200	434	0	25,600	0	51,200	0	51,200	0	12,800	—	—	0	6,400
8159	50	102,400	442	100	102,400	50	102,400	0	1,600	0	3,200	—	—	0	3,200
6796	50	6,400	423	50	12,800	0	1,600	0	12,800	0	1,600	—	—	0	400

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