THE BACTERIOLOGY OF BOVINE ABORTION, WITH SPECIAL REFERENCE TO ACQUIRED IMMUNITY.

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Since the general confirmation of Bang's discovery of a characteristic bacillus, *Bacillus abortus*, associated with abortion in cattle in different countries and the successful production of disease of the fetal membranes through infection of pregnant cows with *Bacillus abortus* in pure culture, it has been taken for granted that Bang's bacillus was the sole infectious agent, and further research into the etiology has given way to the study of methods of diagnosis, of vaccines, and their application.

The bacteriological study of cases of abortion as they occurred in a large herd in which a fair proportion of the stock was bred on the spot with accessions from other herds from time to time, continued over a period of $2\frac{1}{2}$ years, has shown that while *Bacillus abortus* may be the sole agency of abortion in certain herds, this is clearly not true for the herd under investigation.

In view of this somewhat unexpected result it seemed desirable to go over the data pertaining to the various cases in some detail, first, to see how far the bacteriological results could be depended upon to give information concerning the nature of the infectious process leading to death and expulsion of the fetus, and second, to note the bearing of the bacteriological data on the acquisition of immunity by the cow against later infection.

Methods.

The methods used for determining the presence or absence of infectious agents in the fetus and fetal membranes were those directed towards finding *Bacillus abortus* and spirilla (*Vibrio fetus*). Bits of

tissue from lungs, spleen, liver, and kidneys, and several drops of fluids from the different sections of the digestive tract of the fetus were added to slanted agar and the tubes sealed with sealing-wax. At the same time guinea pigs were inoculated with salt solution suspensions of contents of the digestive tract, portions of lungs, fetal membranes, and of swabs from the uterus whenever obtainable. For the details of the method of using guinea pigs and the results obtainable, the reader is referred to the communication by Smillie.[1]

In general, cultures will not succeed unless the amounts of fluid or tissue transferred to culture tubes are adequate. Usually bits of tissue the size of small beans or fluids of equivalent amount are sufficient. But even with these the growth may be limited to the condensation water and the adjacent portion of the slant on account of the few bacteria contained in the material.

As to the relative delicacy of the two methods—cultures direct from the fetus and guinea pig inoculations—in revealing the presence of a very few abortion bacilli, it may be stated that in most cases direct cultures and guinea pig inoculations agreed in being either both positive or both negative. In a few cases, however, in which the inoculation of guinea pigs failed to produce either manifest lesions or positive cultures from the spleen, the direct cultures showed the presence of a very few abortion bacilli. The method of direct culture may therefore be considered superior to the guinea pig test under conditions assuring pure cultures.

Under other conditions the use of guinea pigs must replace largely the cultures. Fetuses over 7½ months old may be born alive. In that case they inspire a little air and swallow some saliva or bedding before they die. The invasion of miscellaneous bacteria goes on very rapidly and cultures with lung tissue or fluids from the stomachs will usually be overgrown with a variety of forms. Guinea pigs inoculated with such material may show the presence of *Bacillus abortus* unless the invasion has gone too far, when the guinea pigs may rapidly succumb to a miscellaneous infection in which pathogenic anaerobes figure largely.

To obtain pure cultures of *Bacillus abortus* from the fetal mem-

[1] Smillie, E. W., *J. Exp. Med.*, 1918, xxviii, 585.

branes, the indirect method of inoculating guinea pigs is usually the only one successful, unless the placenta is promptly discharged and, if soiled, the diseased portions are repeatedly washed in sterile water or salt solution. This procedure removes much of the infection itself in the shape of infected epithelium and phagocytic cells, but it leaves enough to make isolation of *Bacillus abortus* possible. The material is transferred to an agar slant and well distributed over the surface. A loopful from this is transferred to a second, and so on to a third or fourth and the tubes are sealed.

When the placenta remains within the uterus 24 hours or longer, the miscellaneous infection becomes so great that guinea pigs inoculated with uterine fluid or suspensions of placental tissue rarely survive a septic infection resembling that due to malignant edema or *Bacillus welchii*, unless very small doses are injected and three or four guinea pigs used. Retention of the placenta *in utero* following abortion is the rule, and therefore cultures and guinea pig inoculations of discharges are likely to fail because of the predominance of other bacteria. Even when the placenta is discharged in part it may be in a condition which precludes the successful isolation of *Bacillus abortus*.

The question then arises how far the results obtained from cultures and guinea pig tests of fetal tissues and fluids can be depended on to assure a diagnosis. In other words, is the fetus invariably infected with *Bacillus abortus* when the placenta is involved? If not, what is the percentage of abortions in which *Bacillus abortus* fails to be demonstrable in the fetal organs by the method described?

This, like other questions involving bacteriological methods, can be answered only through cumulative data. It is impossible to subject the entire fetus to bacteriological tests, and the bacteria may be so scarce or so unevenly distributed in the digestive and respiratory tracts as to escape the culture tube. The data on which this paper is based contain a small percentage of cases in which both fetus and placenta were cultured and tested on guinea pigs. This material will be fully discussed in another publication, and we can merely give results here which go to show that in perhaps not more than one out of twenty-five cases were cultures from the fetus negative and guinea pig inoculations from placental tissue or uterine discharges positive.

It may on the whole be accepted, therefore, that only a very small proportion of abortions due to *Bacillus abortus* occur before the fetus has been invaded. Even in the case of certain fetuses born alive which survived from 1 to 7 days, *Bacillus abortus* was isolated from the lungs through guinea pigs. Owing to the presence of septic organisms the intestinal contents in such cases cannot be inoculated into guinea pigs without inducing a rapidly fatal septic infection in most animals.

Grouping of Cases According to the Associated Bacteria.

In the tables the cases, for convenience, have been divided into four groups: (1) the cows raised within the herd, from which *Bacillus abortus* was isolated; (2) the cows introduced into the herd from without, from which *Bacillus abortus* was isolated; (3) cases of infection with *Vibrio fetus*; (4) cases of abortion in which cultures remained sterile and guinea pig inoculations negative, or which were associated with other agencies such as *Bacillus pyogenes*.

In Table I there are 37 cases from which *Bacillus abortus* was isolated. Of these, 26 were first pregnancies, 7 were second pregnancies, 3 were third pregnancies, and 1 was a fourth pregnancy. Of the cows aborting in the second pregnancy, 4 aborted both times and 1 had a normal first gestation. Of the 3 cows aborting in the third pregnancy, one is recorded as having aborted in the second pregnancy. The other 2 have no record of previous abortions. One aborting in the fourth pregnancy has no record of earlier abortions.

In Table II are brought together all purchased cows whose fetuses or calves or fetal membranes were found infected with *Bacillus abortus*. Some of these cows had given birth just before purchase. Some gave birth soon after purchase. In the third column are given all calvings between the time of introduction into the herd and the abortion or premature delivery of calves. If the period between acquisition and the first calving thereafter is a month or less, the next pregnancy may be considered the first in which infection with *Bacillus abortus* became possible in the new surroundings. In such cases, therefore, the second pregnancy has been designated the first in the table.

TABLE I.

Native Cows, Aborting or Giving Birth to Living Calves from Which B. abortus Was Isolated.

Case No.	Length of fetus.	No. of calving.	Remarks.
2	46 cm.	2	Aborted both times.
16	Destroyed.	1	Placenta inoculated.
17	27 in.	1	
19	Calf alive.	2	
21	25 in.	1	
22	23 "	1	
26	?	1	
30	Nearly mature.	3	2 wks. premature. No record of earlier abortions.
31	27 in.	1	
33	26 "	1	
41	Nearly mature.	1	
78	28 in.	1	
86	21½ "	1	
89	Alive.	1	
105	19½ in.	3	Aborted also in second pregnancy.
120	14 "	2	First calf normal.
134	Calf alive.	1	Placenta inoculated.
146	Fetus not found.	1	" "
150	30½ in.	1	*In utero.*
153	2 cm.	2	
164	Alive.	1	
180	33 in.	1	Fetus lived several hrs.
200	21 "	1	
203	Alive.	1	
206	28 in.	1	
210	Calf alive.	1	
215	" "	1	
224	" "	1	
227	" "	1	
229	(80 lbs.)	1	
266	31 in.	3	No record of earlier abortions.
285	28½ "	1	
298	34 "	1	
301	Alive.	2	Calf killed when 7 days old. Cow aborted in Mar, 1917. (See No. 21.)
313	29 in.	4	No record of former abortions.
316	22¼ "	2	Aborted both times.
342	25¼ "	2	" " "

This group illustrates the fact, already recognized by owners of herds, that cows introduced into an infected herd from a clean herd will abort sooner or later and in this respect act as heifers raised in the herd. They have no protecting immunity. Among the twenty-five cases of Table II are sixteen which may be considered as aborting at the first opportunity; *i.e.*, during what may be called their first pregnancy in the new herd. Seven aborted in the second pregnancy and only two in the third.

Taking together the two groups of 62 cases from which *Bacillus abortus* was isolated either directly or through guinea pigs or with both methods, we find the following classes according to the number of pregnancies: Abortion at first pregnancy, 42; of these 26 were native heifers and 16 purchased cows. Abortion at second pregnancy, 14; of these 7 were native and 7 purchased cows. Abortion, at third pregnancy, 5; 3 were native cows and 2 purchased.

The group of 26 cases from which pure cultures of spirilla have been obtained has been tabulated in other publications.[3,3] Of these only 3 were native cows. The fetuses of these represented the third, sixth, and eighth pregnancy respectively. Among the purchased cows 6 cases were first, 9 second, 5 third, and 3 fourth pregnancies since purchase.

The fourth group of cases from which neither *Bacillus abortus* nor *Vibrio fetus* was isolated forms the most miscellaneous group and one most difficult to analyze. Of the twenty-one cases sufficiently studied through cultures, guinea pig inoculations, and the histological material to deserve a place in the table, one or two may possibly belong to the group of *Bacillus abortus*. Several may come within the group of *Vibrio fetus;* two were cases of infection with *Bacillus pyogenes* in which the preceding pregnancy had been cut short by *Bacillus abortus* infection. In eight, miscellaneous, rapidly growing bacteria appeared in the cultures. Of these several may be regarded as cases in which bacteria gained entrance immediately after expulsion, the fetus being large enough to have lived a short time after birth. One was clearly a case of asphyxiation at birth (No. 126) and one regarded by the

[2] Smith, T., *J. Exp. Med.*, 1918, xxviii, 701.
[3] Smith, T., *J. Exp. Med.*, 1919, xxx, 313.

TABLE II.

Purchased Cows, Aborting or Giving Birth to Living Calves from Which B. abortus Was Isolated.

Case No.	Date of purchase.	Date of calvings after purchase.	Date of abortion.	Size of fetus.	No. of calvings after purchase associated with *B. abortus*.
			1917		
20	Nov. 25, 1915		Mar. 16	Alive.	1
91	Apr. 19, 1917		June 5	30 in.	1
111	Nov. 20, 1915	Sept. 29, 1916	July 16	38 "	2
129		Oct. 2, 1915 " 28, 1916	Aug. 22	Alive.	2
131	July 14, 1914	July 9, 1915 Aug. 12, 1916	" 30	28 in.	3
			1918		
205	Dec. 14, 1916		Feb. 19	Twins; 35 and 36½ in.	1
214	Apr. 19, 1917	Apr. 24, 1917	Mar. 15	Alive.	1
222	July 25, 1916		Apr. 11	"	1
226	Apr. 3, 1916	Apr. 22, 1917	" 12	"	2
253	Aug. 17, 1917	Oct. 1, 1917	June 13	25 in.	2
270	Oct. 12, 1916	" 16, 1916 Sept. 6, 1917	Aug. 22	29½ "	2
273	Nov. 13, 1917	Nov. 20, 1917	" 27	16 "	1
275	Apr. 19, 1917	May 26, 1917	Sept. 2	16¼ "	1
276	Nov. 20, 1915	1917	" 4	20½ "	2
278	" 10, 1917		" 19	14½ "	1
281	" 13, 1917		Oct. 4	30½ "	1
305	Aug. 17, 1917	Sept. 16, 1917	Dec. 24	21½ "	1
			1919		
309	Apr. 6, 1918		Jan. 2	(58 lbs.)	1
311	Aug. 19, 1917		" 7	(38 ")	1
325	Nov. 13, 1917		Feb. 12	36 in.	1
328	Apr. 20, 1917	Aborted Apr. 13, 1918	Mar. 9	31 "	2
329	" 18, 1918		" 11	30 "	1
343	Oct. 12, 1918		Apr. 13	14½ "	1
350	Feb. 9, 1917	Aborted in Nov., 1917, and in May, 1918.	" 30	Alive.	3
351	May 12, 1918	May 25, 1918	May 5	28 in.	1

TABLE III.

Cases of Abortion from Which neither B. abortus nor Vibrio fetus Was Isolated.

Case No.	Length of fetus.	No. of pregnancy.	Purchased or raised.	Date of abortion.	Cultures from.								Remarks.
					Stomach.	Small and large intestines.	Meconium.	Lungs.	Liver.	Spleen.	Kidneys.	Fetal membranes.	
				1916									
4	(8 mos.)	?	Raised.	Apr. 1		—*		—	—		—		No earlier abortions.
35	16½ "	1	Purchased.	" 14				—	—		—		
				1917									
103	4 in.	3	Raised.	June 24								2 g. p.—	No earlier abortions.
122	24 "	1	Purchased.	July 31	Moulds. g. p.—	Moulds. g. p.—			Cocci.	—	—	g. p.—	
126	(75 lbs.)	2	" Sept. 4, 1915.	Aug. 15	— g. p.—	— g. p.—		—	—	—	—	2 g. p.—	Calf probably asphyxiated during birth.
143	(35 ")	1	Purchased Aug., 1917.	Oct. 11	g. p.—			—	—	—	—	2 g. p.—	Cow said to have been fighting few days before abortion.
158	12½ in.	1	Purchased Feb. 16, 1917.	Nov. 6								3 g. p.—	Calved Mar. 10, 1917. Probably a case of spirillum infection.
				1918									
201	34 "	2	Purchased 1917.	Feb. 12	Cultures overgrown.		— 2 g. p.—	Cultures overgrown. 2 g. p.—	—	—	—		Lungs partly inflated.
202	15½ "	4	Purchased Sept. 28, 1917.	" 13	—		— g.p.—	— g. p.—	—	—	—		No record of earlier abortion.

211	23 in.	4	Raised.	Mar. 13	— g. p.—		— g. p.—	—	—	—	—		Preceding calving 2–3 wks. premature (No. 30). *B. abortus* isolated at that time.
259	20 "	2	"	July 18			g. p.—	*B. pyogenes.* g. p.—	*B. pyogenes.*		*B. pyogenes.*		Aborted Oct. 22, 1917 (No. 146).
261	30½ "	6	Purchased Sept. 28, 1912.	" 26	— g. p.—		— g. p.—	— g. p.—	—	—			No record of earlier abortions. Lungs not inflated.
262	29 "	1	Purchased Dec. 5, 1916.	" 28	Streptococcus. g. p.—		— g. p.—	Colon bacillus. g. p.—	—	—	Heavy growth.		Lungs not inflated.
265	20 "	4	Raised.	Aug. 4			— g. p.—	Cultures contain *B. coli* types. 2 g. p.—					Calved Feb. 27, 1916. Aborted Aug. 30, 1916. Calved Dec. 20, 1917.
277	32 "	2	"	Sept. 11	Cultures overgrown.	Cultures overgrown.	— g. p.—	Moulds. g. p.—	—	—	—		Premature calf, 7½ mos. Alive. Cow calved normally Aug. 30, 1917.
279	8 "	2	"	" 27				— g. p.—				g. p.—	Aborted Jan. 20, 1918 (first pregnancy). Not studied.
282	Alive.	5	Purchased Aug. 21, 1912.	Oct. 8	Cultures overgrown. g. p.—		— g. p.—	Cultures overgrown. g. p.—					2 wks. premature.

* — indicates negative cultures; g. p. —, negative results with reference to *B. abortus* following the inoculation of guinea pigs.

TABLE III—*Concluded.*

Case No.	Length of fetus.	No. of pregnancy.	Purchased or raised.	Date of abortion.	Cultures from.								Remarks.
					Stomach.	Small and large intestines.	Meconium.	Lungs.	Liver.	Spleen.	Kidneys.	Fetal membranes.	
				1918									
291	32 in.	4	Raised.	Nov. 19	*B. pyogenes.* g. p.—		— g. p.—	*B. pyogenes.* g. p.—	*B. pyogenes.*			g. p.—	No record of previous abortions. Fetus dead some time before expulsion.
300	35 "	6	Purchased Oct. 10, 1911.	Dec. 7	— g. p.—	Stomach—	— g. p.—	— g. p.—	—	—	Cultures overgrown.		Lungs not inflated.
				1919									
327	36 "	1	Purchased Aug. 10, 1917.	Feb. 18	Cultures overgrown. g. p.—		— g. p.—	— One culture overgrown. g. p.—	—	—	—	g. p.—	
344	36½ "	3	Purchased Aug. 20, 1916.	Apr. 12	— g. p.—	Stomach—	—	— g. p.—	—	—	Contaminated.	g. p.—	Calved in 1916 and 1917.

attendants as traceable to fighting several days before expulsion of fetus (No. 143). Seven may be considered bacteria-free or sterile. How many of these are due to injury, to toxic substances, and to food factors cannot be stated. The importance of these cases, because not associated with *Bacillus abortus*, has warranted a rather detailed publication of the data in Table III.

In this group too there are no first pregnancies. Those marked first in the table refer to purchased cows and are at least second pregnancies. Thirteen are purchased and eight native cows. The pregnancies during which the fetuses were dropped prematurely range from first to sixth.

Summing up the bacteriological data from another point of view we have 47 cases from which *Bacillus abortus* was not isolated. Among the latter were 25 cases associated with *Vibrio fetus* and 1 case containing a related but not identical spirillum; 2 with *Bacillus pyogenes*; 7 with sterile digestive and respiratory tracts; and 7 with only cultures of the digestive tract and lungs fertile, due chiefly to aspiration and swallowing of miscellaneous bacteria at birth.

Acquired Immunity to Bacillus abortus.

A statement frequently made in veterinary literature and by stock owners is that cows gradually lose the tendency to abort. This tendency is in harmony with the nature of the abortion disease,—an invasion of the fetal membranes, more particularly the chorion, by infectious agents, followed by multiplication of the latter and more or less injury to the tissues attacked.

The rapidity with which immunity is acquired varies considerably. Holth[4] quotes one observer as giving the experience of thirty veterinarians to the effect that cows tend to abort two or three times in succession. He quotes another observer as claiming that 68 per cent of aborting cows aborted but once, and Bang as stating that of 83 aborting heifers only 20 aborted next time. In most infectious diseases the young are attacked in largest numbers. Hence we would expect the largest number of abortions among primiparæ (heifers). But even here observations differ. Holth quotes an observer as

[4] Holth, H., *Z. Infektionskrankh. Haustiere*, 1911, x, 342.

stating that only 36 per cent of the cows under his care calved normally, whereas 45 per cent of the heifers did so.

In the tables it is evident that abortion is essentially a disease of young stock and that second and third abortions are less common. If we control the data by the bacteriological results obtained, we find that relatively few cows are subject to disease of the fetal membranes due to *Bacillus abortus* twice. Abortions do occur in succession but they are due chiefly to causes other than *Bacillus abortus*. In illustration of this fact the following consecutive abortions studied bacteriologically are noteworthy. The individual abortions have been given case numbers; each pair of numbers therefore refers to one and the same cow.

Case 3.—Cow aborted Feb. 23, 1916. Had six or seven normal calves before. Fetus contained within membranes, about 6 to 7 inches long. Fetus has undergone autolytic changes. Only head, limbs, and ribs recognizable. The entire mass has a reddish, translucent, gelatinous appearance. Guinea pigs inoculated with suspensions of ground cotyledons remained well. Cultures from spleens negative. This case cannot be considered as having been examined thoroughly bacteriologically, but *B. abortus* was most probably absent.

Case 159.—The same cow aborted Nov. 7, 1917, after having calved normally Feb. 12, 1917. Fetus 16¾ inches long. Some of the placenta discharged. Fetus had been dead *in utero*, probably for some time. From this case spirilla were isolated. Tests for *B. abortus* negative.

Case 146.—Holstein heifer aborted on pasture Oct. 22, 1917. Fetus could not be found. A portion of placenta removed next day. All of twelve guinea pigs inoculated from this for another experiment were found infected with *B. abortus* when chloroformed. *B. abortus* also identified in sections of placenta.

Case 259.—The same cow aborted July 18, 1918. Fetus 20 inches long. General subcutaneous, blood-tinted edema. Some of abdominal organs eaten out by some animal. Thorax full of blood-tinted fluid. Fetus probably dead some time as autolytic changes were prominent. Cultures from intact organs—lungs, liver, and kidneys—show large numbers of colonies of a bacillus diagnosed as *B. pyogenes*. Guinea pig tests of lung and meconium negative.

Case 30.—Calved Apr. 3, 1917, but calf lived 2 hours only. Probably 2 weeks premature. This cow had calved normally in 1914 and 1916. *B. abortus* was isolated from the uninflated lungs both in cultures and through guinea pigs.

Case 211.—The same cow aborted Mar. 13, 1918. Placenta retained. Fetus 23 inches long; has undergone more or less maceration *in utero*. Cuticle peels off readily. Large serous cavities filled with blood-tinted fluid. Edema of subcutis and muscular tissue, blood-stained. Cultures from this case remained sterile. Guinea pig tests also negative.

Case 19.—Cow gave birth to twin calves Mar. 13, 1917 (second pregnancy). Both very weak, unable to stand and too weak to drink. One calf died Mar. 15, of scours. Extensive fatty degeneration of liver. Many collapsed lobules throughout left lung and in ventral lobe of right lung. Two guinea pigs inoculated with suspension of ground lung tissue in salt solution became infected with *B. abortus*.

Case 290.—The same cow on Nov. 19, 1918, gave birth to a fetus 24 inches long. Placenta retained. Guinea pig inoculations negative as to *B. abortus*. Spirilla in pure culture isolated from fourth stomach and colon contents, from liver, spleen, kidney, and lungs.

Case 21.—Heifer aborted Mar. 20, 1917. Fetus about 25 inches long. General subcutaneous edema. Large serous cavities filled with blood-tinted fluid. From the placenta *B. abortus* was isolated through a guinea pig.

Case 301.—The same heifer was bred four times and gave birth on Dec. 11, 1918, to a calf apparently normal. Placenta retained; cow was discharging from vagina. A swab containing such discharge washed out in salt solution and the latter injected into two guinea pigs. From both *B. abortus* was subsequently isolated. The calf did not do well and was killed when 7 days old. One umbilical artery close to umbilicus was involved in suppuration. Multiple foci of collapse in both ventral lobes. From a guinea pig inoculated therewith *B. abortus* was isolated.

Case 246.—Fetus 7 to 8 inches long found enclosed in membranes on the morning of May 28, 1918. Autolytic changes far advanced. No odor of bacterial decomposition. Spirilla were isolated in pure culture from the lungs and liver. No other bacteria found in the fetus. Guinea pigs inoculated with material from the same organs were normal when chloroformed after 6 weeks. This cow was purchased Sept. 2, 1917, and aborted in Nov. of the same year. The fetus from this abortion was not received for study.

Case 350.—The same cow aborted a third time Apr. 30, 1919. Fetus, due June 4, alive at birth and able to stand. Weighs 57 lbs. Killed about 4 hours after birth. Autopsy shows that no food had been taken but the rumen contained besides the fetal fluid much froth from swallowed saliva. No abnormalities were detected. The placenta was retained and films from a swab inserted into uterus showed groups of bacteria resembling *B. abortus*. Cultures from the stomachs were impure mixtures, as might have been expected, but those from colon and rectum contained only *B. abortus*. A guinea pig inoculated with salt solution suspension from the swab, chloroformed after 7 weeks, was found with the lesions of *B. abortus*.

These six pairs of consecutive abortions indicate in general an acquired immunity to *Bacillus abortus*. In three pairs the first abortion was associated with *Bacillus abortus*, the second with negative cul-

tures, *Bacillus pyogenes*, and spirilla respectively. In one pair both abortions were associated with *Bacillus abortus*. In one pair *Bacillus abortus* was not detected either time. The first abortion may or may not have been associated with spirilla, since the condition of the material (advanced autolysis) did not warrant cultures, except from the spleen. These were negative. Later studies indicated that the spleen is rarely invaded by spirilla. The last case is exceptional. Of the first abortion there is no record. It may or may not have been due to *Bacillus abortus*. The second abortion was associated with spirilla. The third, associated with *Bacillus abortus*, may have been due to reinfection from the udder following loss of immunity acquired on account of the first abortion.

Were it not for agents other than *Bacillus abortus*, such as *Vibrio fetus*, and to a far less degree to miscellaneous septic and pyogenic organisms, and to unknown, non-bacterial agencies, second and later abortions by the same cow would be relatively rare. It therefore becomes necessary in the future to distinguish between the tendency of any given cow to abort repeatedly and the relation of *Bacillus abortus* to such repeated abortions. If abortions are due to a variety of infectious and non-infectious agencies, a better knowledge of abortion can only be reached by a patient, thorough study of series of individual cases, followed by the necessary experimental tests in order that these agencies may be assigned their proper place. A further analysis of this material will be found elsewhere.[5] It is there shown that the udders of a relatively high percentage of cows become infected with *Bacillus abortus* probably during the first abortion disease. Cows while carrying *Bacillus abortus* in the udder may give birth to normal calves, or to fetuses infected with spirilla, or to sterile fetuses. Probably the udder becomes a protecting reservoir of immune bodies towards *Bacillus abortus*.

SUMMARY.

In a large herd of dairy cattle and young stock the bacteriological examination of 109 cases of abortion which included a relatively thorough study of the fetus and a study of the membranes, or swabs from

[5] Smillie, E. W., Little, R. B., and Florence, L., *J. Exp. Med.*, 1919, xxx, 341.

the uterus whenever obtainable, gave the following results. 62, or 57 per cent, were associated with *Bacillus abortus*. 26, or 23.8 per cent, were associated with spirilla. 2, or 1.8 per cent, were associated with *Bacillus pyogenes*. 19, or 17.4 per cent, were either sterile or else the digestive and respiratory tracts had been invaded during or after birth with miscellaneous bacteria. *Bacillus abortus* was absent according to cultures and animal tests.

Such a relatively large proportion of cases of abortion without *Bacillus abortus* as the inciting agent is noteworthy. In general *Bacillus abortus* was associated with first pregnancies. Its presence diminished rapidly in frequency in later pregnancies. Assuming in a general way that purchased cows coming from small herds were free from any immunity and that their first pregnancy in the new herd is equivalent to that of a native heifer and may be counted as the first, we have *Bacillus abortus* associated with the first pregnancy in 42, with the second in 14, with the third in 5, and with the fourth in 1. Spirilla were distributed as follows: (*a*) in purchased cows, first pregnancy, 6; second pregnancy, 9; third pregnancy, 5; and fourth pregnancy, 3; (*b*) in native cows, first pregnancy, 0; third pregnancy, 1; sixth pregnancy, 1; and eighth pregnancy, 1. The relation of infection with spirilla to acquired immunity is not clear and more data from large herds are needed to define both etiological and immunological bearings of the spirilla.

Thus far spirilla have not been encountered in native heifers of the herd giving birth the first time. A tentative explanation to be offered is that the young stock is kept segregated from the older and purchased cows until shortly before calving. The occasional discharge of a fetus among the young stock in pasture tends to keep up the disease due to *Bacillus abortus*. Later on association with older cows brings about infection with spirilla (*Vibrio fetus*) and more rarely with other possible agencies of fetal disease. On the other hand, abortions may occur among the pastured stock from time to time and remain unrecognized. Not until both groups of animals are subjected to the same daily scrutiny will it be possible to affirm that abortion associated with spirilla does or does not occur among young stock.