

## **Studies on the Alimentary Tract of the Merino Sheep in South Africa.**

### **I.—Investigations into the Physiology of Deglutition.**

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THIS paper is the first of a series of "Studies on the Alimentary Tract of the Merino Sheep in South Africa." The staff of Onderstepoort, realising the tremendous importance of an exact knowledge of all matters relating to the alimentary tract of the sheep, have drawn up a comprehensive programme which includes embryology, anatomy (macro- and microscopic), physiology (physical and chemical), bacteriology and protozoology, to be studied on sheep of all ages under normal conditions, abnormal dietary conditions and pathological conditions due to worm infection and other causes. These investigations will not be conducted in an absolutely systematic manner, but any single question may be studied when a suitable opportunity arrives and the same material is also to be used for the study of other aspects of the problem as far as possible. It is, however, the intention that a special effort should be made to devote as much time as possible to this problem.

#### **INTRODUCTION.**

The work recorded here was started on account of difficulties experienced in connection with the chemotherapy of oesophagostomiasis in sheep (see this Journal) with the object of finding a method which would ensure the direct passage to the abomasum of drugs administered per os. The importance of this matter is discussed in the article referred to above. A study on the physiology of deglutition in a ruminant covers a very wide field and the investigations had to be restricted, for obvious reasons, on account of the practical nature of the object in view. The main question was the possibility of administering drugs in the form of powders into the abomasum and the method had to be sufficiently simple in order that it could be applied in practice by farmers handling large numbers of sheep.

A number of investigators have studied the route taken by substances, especially fluids, administered to sheep per os. It is not intended here to enter into a full discussion of their results, especially as this article is concerned with the administration of solids and most of the work done in the past was concerned with nothing more than a determination of the route taken by materials, especially fluids, after ordinary administration. It is, however, clear from the previous investigations, that powders are not regularly swallowed by sheep into the abomasum. Sprehn (1931) records tests made by him with small tablets, weighing 0.2 gm. each, in which he found that such tablets passed directly to the abomasum. These tests were, however, done on a few sheep only and the good results obtained by treating sheep in this way for stomach worms is no proof that the tablets are always swallowed through. Oppermann and Behrens (1932) were not able to confirm the results of Sprehn and the present investigations also do not support them.

The physiology of deglutition, with special reference to the oesophageal groove and the importance of the problem in connection with the administration of drugs has been studied on cattle by Wester (1930) in great detail. This work is of outstanding importance and lays the foundation for all further investigations in this direction, although it will be seen that the sheep used by us frequently reacted quite differently from Wester's cattle. This may perhaps be explained by the fact that the sheep were not unusually tame, while the cattle may have become accustomed to frequent handling and examination through the rumen fistula. Wester remarks that sheep may react like cattle, but that this remains to be proved experimentally.

As far as this paper is concerned, the findings of Wester can be summarised as follows:—

In the very young animal the oesophageal groove closes reflexly during the act of drinking, so that milk and water pass directly to the abomasum.

The reflex for water soon decreases, so that in older calves a portion enters the fore-stomachs and in adult animals the whole quantity, while the reflex for milk persists a long time. However, in relatively young, thirsty animals the reflex comes into action again after a few mouthfuls of water have been swallowed and the abomasum is first filled before the rest passes into the fore-stomachs. In older animals also the reflex closing of the groove can be stimulated by means of suitable fluids more readily when the animals are thirsty than under normal conditions. After drinking a large quantity of water the reflex is sometimes much less readily stimulated. The reflex is initiated in the anterior part of the oesophagus or the pharynx by stimulation of the vagus endings there and the oesophageal groove closes immediately after deglutition. Fluids administered by stomach tube will therefore not cause closing of the groove and will enter the rumen. This reflex can be stimulated by the albumin of milk and possibly also the globulin, and further by sodium salts, especially Sodium chloride and sodium bicarbonate and sugar. The speed and intensity of the reaction depend on the concentration of these substances. Other stimulants tested had little or no effect.

As a practical method of dosing young, healthy cattle, into the abomasum, Wester recommends keeping the animals from water for 24 hours, then dosing with 100-200 c.c. of a 5-10 per cent. sodium bicarbonate solution, followed by the drug together with milk, bloodserum or preferably 5-10 per cent. bicarbonate solution, after an interval which is sufficiently long to allow closure of the groove to take place.

### EXPERIMENTAL WORK.

In the following tests a red powder was usually administered after preliminary treatment of the sheep, which were killed after a definite interval, cut open and examined to determine the route taken by the powder. Red mercuric sulphide, carmine and red lead oxide were used, being well visible, relatively insoluble, heavy (except carmine), fine of texture and apparently not irritating to the mucous membranes.

The results are given in tabulated form for the sake of brevity.

The sheep used in these tests were fed on dry hay with a ration of crushed maize and received no green food. Water was always accessible unless it was specially withheld.

## TEST I.

No special preparation. Sheep 1-4 dosed with a level teaspoonful of red HgS, 1-2 killed immediately, 3-4 killed 10 minutes after dosing. Sheep 5 given level teaspoonful dry NaCl followed  $\frac{1}{2}$  minute later by HgS; sheep 6 similar with interval of 1 minute; sheep 7 given 1 tablespoonful concentrated NaCl solution followed  $\frac{1}{2}$  minute later by HgS, sheep 8 similar with interval of 1 minute. Sheep 5-8 killed immediately after dosing.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
1.....	4	o	f	+	—	—	2	8	—	—
2.....	4	o	g	+	—	9	1	—	—	—
3.....	6	f	f	—	—	—	2	2	5	1
4.....	4	o	g	—	—	—	1	1	4	4
5.....	6	o	g	+	—	4	—	—	6	—
6.....	4	o	g	+	—	—	—	—	10	—
7.....	4	f	g	+	—	4	—	—	6	—
8.....	6	o	g	—	—	4	3	3	—	—

*Remarks.*—Age: 1=lamb; 2, 4, etc.=2-tooth, 4-tooth, etc.

Sex: m=male, ram; f=female, ewe; o=wether.

Condition: g=good; f=fair; m=moderate, slightly poor; p=poor.

Rumen consistence: +=semi-solid; ±=semi-fluid; —=fluid.

Gas: +=fair to large amount present in rumen and reticulum.

The red powder is considered to consist of ten parts of which the distribution is given under the headings Mouth, if not all was swallowed, Rumen, Reticulum, Omasal groove and Abomasum.

*Discussion.*—Without stimulation the powder does not regularly pass to the fourth stomach, as has been shown by many previous investigations. Stimulation with NaCl appears to direct the powder through the oesophageal groove. It is not clear whether the consistence of the ruminal contents plays a part; the results with sheep 5-8 seem to uphold Wester's idea that a thirsty animal is more readily stimulated than one that is not thirsty.

## TEST II.

In order to see whether thirsty animals are more readily stimulated, these sheep were kept from water for 18 hours. Sheep 9-12 were given a level teaspoonful of NaCl followed by HgS after 1, 2, 3 and 5 minutes respectively and sheep 13-16 were similarly treated but got NaHCO<sub>3</sub> instead of NaCl. All were killed 5-10 minutes after dosing.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
9.....	8	m	g	+	—	5	1	—	3	1
10.....	6	f	g	+	—	—	5	5	—	—
11.....	6	o	f	±	—	—	8	12	—	—
12.....	4	f	f	+	—	—	7	2	1	—
13.....	4	f	f	+	—	—	4	3	3	—
14.....	4	o	f	+	—	2	2	—	3	3
15.....	4	o	f	+	—	—	9	—	1	—
16.....	4	o	f	+	—	—	9	1	—	—

*Discussion.*—The intervals of two and five minutes between stimulation and dosing may have been too long.

## TEST III.

Sheep kept from water 18 hours. All were stimulated with NaCl like sheep 9-12 above. The intervals between stimulation and dosing with HgS were 5 seconds for sheep 17-19,  $\frac{1}{2}$  minute for 20-21 and 2 minutes for 22-24. All killed 5 minutes after dosing in this and subsequent tests.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
17.....	6	f	f	+	—	—	—	—	2	8
18.....	4	o	g	+	—	4	—	—	2	4
19.....	2	o	m	++	—	—	2	6	2	—
20.....	4	o	m	+	—	—	8	1	1	—
21.....	4	o	f	+	—	4	2	2	2	—
22.....	4	o	p	++	—	4	6	—	—	—
23.....	4	o	m	++	—	—	6	—	4	—
24.....	2	o	f	+	—	—	6	2	2	—

*Discussion.*—The interval of 5 seconds was suitable in two of three cases; the third may have been affected by the condition of the sheep, but it will be seen later that this is not necessarily the case. Sheep 24 was young and should have swallowed well; the interval of 2 minutes may have been too long.

## TEST IV.

Sheep kept from water 18 hours. Stimulated with NaCl as before and dosed with HgS after 5 seconds, sheep 25-28 and 1 second, sheep 29-32. The sheep were selected on account of poor condition.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
25.....	8	m	m	+	—	—	1	1	8	—
26.....	2	f	m	+	—	—	3	2	5	—
27.....	4	o	f	—	—	5	5	—	—	—
28.....	4	o	m	+	—	—	1	—	1	8
29.....	6	f	p	++	—	—	8	—	2	—
30.....	4	o	p	++	—	—	1	1	—	8
31.....	4	f	p	+++	—	2	2	6	—	—
32.....	4	o	p	++	—	2	6	1	1	—

*Discussion.*—There are good indications of sufficient stimulation after 5 seconds. Sheep 27 with fluid contents in rumen poorly stimulated, also 29, 31 and 32, with semi-fluid contents. The others with semi-solid contents well stimulated.

## TEST V.

The sheep were kept from water for 18 hours. All dosed with HgS 5 seconds after stimulation with level teaspoonful dry NaCl. Lamb 36 was 2½ months old. Sheep 37 and 38 were each given 2 litres water by stomach tube half an hour before dosing in order to determine the influence of consistence of the ruminal contents.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
33.....	4	f	m	+	—	—	3	2	5	—
34.....	6	f	g	++	—	4	4	2	—	—
35.....	8	o	g	+	—	—	—	1	2	7
36.....	1	f	f	++	—	—	3	5	2	—
37.....	4	o	g	—	—	—	1	1	—	8
38.....	8	o	g	±	—	—	1	1	7	1

*Discussion.*—The result with lamb 36 is quite contrary to expectation. Sheep 37 and 38 swallowed best of all, the rumen and reticulum containing traces only.

## TEST VI.

In order to determine further the effects of thirsting and starvation, the sheep were kept from food and water for 22 hours. Dosed as in Test V. Sheep 42 and 43 received each 2 litres water by stomach tube half an hour before dosing.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
39.....	8	f	g	±	—	—	—	—	6	4
40.....	1	f	g	±	—	—	—	—	8	2
41.....	4	f	g	++	—	—	—	4	6	—
42.....	8	o	g	—	—	4	1	—	5	—
43.....	6	f	g	—	—	—	—	—	—	10

*Discussion.*—Sheep 42 did not swallow properly but the direction was satisfactory. Only sheep 41 with semi-solid ruminal contents did not swallow through completely. In these sheep the starvation did not affect the quantity of the ruminal contents to any appreciable degree and the question arises whether the consistence of the ruminal contents, apart from thirstiness, has an influence. Wester states, that the thirsty animal is more readily stimulated than one that is not thirsty. He stimulates the animal by drenching with 100–200 c.c. bicarbonate solution which, although it is a small quantity for a thirsty bovine, may sufficiently moisten the ruminal contents in the anterior portion to have an effect on the reaction of the oesophageal groove. The above tests appeared at first to indicate that semi-solid ruminal contents are desirable and later, that fluid contents give very good results.

## TEST VII.

The sheep were kept from water for 24 hours; 44-47 received salt to lick 90-60 minutes and water 60-30 minutes before dosing; 48-51 received 2 litres water by stomach tube 40-60 minutes before dosing. Dosed as above.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
44.....	2	m	00	++	—	—	1	—	6	3
45.....	8	o	00 00	++	—	—	—	—	2	3
46.....	8	o	00 00 00	++	—	—	—	—	2	3
47.....	8	o	00 00 00	++	—	—	—	—	2	3
48.....	4	m	00 00 00	++	—	—	—	—	2	3
49.....	4	o	00 00 00	—	+	—	—	—	2	3
50.....	6	o	00 00 00	—	—	—	—	—	2	3
51.....	4	o	00	—	—	5	—	—	1	4

*Discussion.*—These results were very satisfactory but difficult to explain in view of previous results and Wester's work. The impression was now obtained, that the ruminal contents should be fluid but the sheep still thirsty, if that is possible.

## TEST VIII.

The sheep were kept from water for 24 hours and allowed to drink one hour to half an hour before dosing. They were apparently not thirsty; only 52 and 53 drank well and 58 and 59 drank a little. Sheep 54 and 55 received each 2 litres water by stomach tube half an hour before dosing and 56-59 were dosed with a level teaspoonful of salt 40 minutes, 20 minutes and 5 seconds before dosing, while 52-55 were dosed as above. In Tests VIII-X carmine was used instead of Hgs.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
52.....	6	o	00 00	++	—	—	2	2	2	4
53.....	4	o	00 00 00	++	—	—	1	1	3	5
54.....	6	o	00 00 00	++	—	—	10	—	—	—
55.....	2	o	00 00 00	++	—	—	5	—	4	1
56.....	8	o	00 00 00	++	—	—	1	—	2	7
57.....	4	o	00 00 00	++	—	—	2	2	6	—
58.....	4	o	00 00 00	++	—	—	4	3	2	1
59.....	6	f	00 00 00	++	—	—	2	2	6	—

*Discussion.*—The results are so variable that it is difficult to draw any conclusions. Sheep 52 and 53 were thirsty, drank well and swallowed fairly well; 54 and 55 were not thirsty, received water by stomach tube and swallowed to the rumen chiefly. In the case of the other four the results are in favour of semi-fluid ruminal contents and the best effect was obtained in the oldest animal which drank nothing.

## TEST IX.

Kept from water 28 hours, then allowed to drink. All drank except 65. Sheep 60 and 61 were dosed 30 minutes; 62 and 63: 45 minutes; 64 and 65: 1 hour; and 66 and 67: 2½ hours after drinking. This test was made especially to see how long the possible effect of drinking would have an influence on the result of stimulation. Sheep 60, 62, 64 and 66 received salt and 5 seconds later Carmine, the others Carmine only.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
60.....	4	f	g	±	—	—	1	—	2	7
61.....	4	f	g	±	—	—	10	—	—	—
62.....	8	f	g	±	—	—	1	—	2	7
63.....	6	f	g	±	—	—	9	1	—	—
64.....	4	f	g	+	—	—	1	1	—	8
65.....	6	f	g	—	—	—	8	2	—	—
66.....	4	f	g	+	—	—	10	—	—	—
67.....	8	f	g	±	—	—	10	—	—	—

*Discussion.*—Sheep 66 was not properly dosed and this result should be discarded. It seems to be clear that stimulation with NaCl is the most important factor. Sheep 64 with semi-solid ruminal contents, stimulated, swallowed through, while 65 with fluid contents, which did not drink and was dosed without stimulation swallowed to the rumen and reticulum. It is not possible to draw definite conclusions with regard to the effect of drinking.

## TEST X.

The sheep were kept from water for 24 hours, then given salt to lick and then water. Only 73 drank a little and all received 2 litres water by stomach tube. Dosed with salt and Carmine 5 seconds later; sheep 68–71: one hour, 72–75: two hours and 76–79: three hours after administration of water.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
68.....	6	o	g	±	—	—	5	3	2	—
69.....	6	o	g	—	+	—	7	3	—	—
70.....	8	f	—	—	+	—	6	3	1	—
71.....	6	o	f	±	+	—	—	—	2	8
72.....	8	o	f	±	—	—	1	—	2	7
73.....	6	f	g	±	—	—	1	—	2	7
74.....	6	o	f	±	—	—	2	—	2	6
75.....	4	o	f	±	—	—	1	1	4	4
76.....	4	f	f	—	+	—	6	2	2	—
77.....	6	o	f	±	+	—	7	3	—	—
78.....	8	o	f	±	+	—	1	—	2	7
79.....	8	o	f	±	+	—	8	—	2	—

*Discussion.*—The gas entered the rumen when the water was administered by stomach tube. Sheep 72–75 dosed two hours after receiving water and, having no gas in the fore-stomachs, swallowed well. Of the others five with gas swallowed badly and two well. Previously sheep 49 also had gas and swallowed well. From this test it seems possible that the gas may have an undesirable effect.

## TEST XI.

Another test like No. X was attempted with the intention that the sheep should drink. They were kept from water 24 hours, then given salt to lick for 30 minutes followed by water for 15 minutes. Sheep 80, 83, 84 and 86 did not drink and the others drank a moderate quantity. They were dosed with salt, followed 5 seconds later by red lead oxide, 80-83 one hour, 84-87 two hours and 88-91 three hours after drinking.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
80.....	8	o	o	+	—	—	7	3	—	—
81.....	8	o	o	—	—	—	—	—	—	8
82.....	2	o	o	++	—	—	—	8	2	—
83.....	4	o	o	+++	—	—	—	—	2	3
84.....	4	o	o	+++	—	—	1	—	9	—
85.....	6	o	o	+++	—	—	1	1	2	6
86.....	6	o	o	+++	—	—	9	1	—	—
87.....	6	o	o	++	—	—	—	—	2	8
88.....	6	o	o	++	—	—	—	—	2	8
89.....	2	o	o	++	—	—	—	—	2	8
90.....	6	o	o	++	—	—	1	1	8	—
91.....	6	o	o	++	—	5	3	2	—	—

*Discussion.*—Sheep 91 swallowed badly. If drinking has an influence, this may still be evident three hours after drinking. The results were, however, so variable that it appeared desirable to investigate other possible factors.

## TEST XII.

The sheep were selected on account of their extremely emaciated condition, which was due to oesophagostomiasis. They had been running on green pastured and were placed in a shed for 24 hours with dry hay and a salt lick, but they took little of either. When they were taken to water it was very cold and raining and none drank. They were dosed with salt, followed after 5 seconds by Carmine in the case of 92-96 and arsenious sulphide in the case of 97-101.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
92.....	2	o	p	—	—	—	—	—	2	8
93.....	6	f	p	—	+	—	6	2	2	—
94.....	2	o	p	—	—	—	2	2	2	4
95.....	4	f	p	±	—	—	2	—	8	—
96.....	8	f	p	—	—	—	—	—	2	8
97.....	8	f	p	—	—	8	1	—	—	1
98.....	2	o	p	—	—	—	—	—	—	10
99.....	4	f	p	—	—	—	—	—	3	7
100.....	4	f	p	—	—	—	—	—	2	8
101.....	2	f	p	—	—	—	—	—	2	8

*Discussion.*—The very fluid ruminal contents of all these sheep, except 95, was rather remarkable. In spite of the extremely poor condition they swallowed very well. The impression was again obtained that the fluid consistence of the ruminal contents had an influence, although the effect of drinking was absent.

## TEST XIII.

In order to see whether the salt and the red lead oxide could be given mixed, i.o.w. whether the groove closes immediately after stimulation, the sheep were kept from water 28 hours and given salt to lick from 5½ hours before dosing up to 30 minutes before, when they were allowed to drink. Sheep 102 and 103 did not drink. The mixture was administered and the sheep killed five minutes later as usual.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
102.....	8	o	ss	++	—	—	1	1	6	2
103.....	8	f	ssss	+++	+	—	10	—	—	—
104.....	6	o	ss	++	—	—	10	—	—	—
105.....	6	o	ss	—	—	—	—	—	2	8

*Discussion.*—No conclusion can be drawn from these results except that the method was not very successful.

## TEST XIV.

To determine the route taken by some anthelmintics without previous stimulation as well as tablets and capsules. The sheep were kept from water for 24 hours, received a salt lick during the last 6 hours and were allowed to drink half an hour before dosing. Sheep 111 and 113 did not drink.

Sheep 106 and 107 received ¼ teaspoonful Government Wireworm Remedy

Sheep 108 and 109 received 10 c.c. liquid Government Wireworm Remedy + Carmine.

Sheep 110 and 111 received 0.5 gm. Copper sulphate + 0.5 c.c. nicotine + 30 c.c. water + magenta.

Sheep 112 and 113 received 3 c.c. CCl<sub>4</sub> + 10 c.c. milk + magenta.

Sheep 114 and 115 received 3 c.c. CCl<sub>4</sub> + 10 c.c. 01·lini + magenta.

Sheep 116 and 117 received each two tablets of 1 cm. diameter.

Sheep 118 and 119 received one 100 mg. capsule filled with Carmine.

Sheep 116–119 were stimulated with NaCl five seconds before dosing.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
106.....	6	o	ss	—	—	—	—	—	2	8
107.....	8	o	ssss	++	—	—	1	1	2	6
108.....	6	o	ssss	++	—	—	—	—	—	10
109.....	8	f	ssss	—	—	—	—	—	—	10
110.....	2	f	ss	—	—	—	—	—	—	10
111.....	6	o	ss	++	—	—	—	—	—	10
112.....	2	f	ss	++	—	—	—	—	—	10
113.....	4	f	ss	++	—	—	—	—	—	10
114.....	6	f	ss	++	—	—	6	4	—	—
115.....	4	f	ss	++	—	—	4	2	2	2
116.....	6	f	ss	++	—	—	—	—	—	2
117.....	6	o	ss	++	—	—	1	—	—	—
118.....	4	o	ss	++	—	—	1	—	—	—
119.....	6	o	ss	—	—	—	—	1	—	—

*Discussion.*—The Government Wireworm Remedy contains Sodium arsenite and copper sulphate and the sodium salt may have stimulated the groove to close. However, it is known from other tests that this Remedy is not regularly swallowed to the abomasum. Concerning the fluids administered to sheep 108–113; it is apparently usually the case that sheep swallow small quantities of fluid to the abomasum, but the sodium salt (108 and 109) and the milk (112 and 113) may have had an influence. On the other hand, sheep 114 and 115 swallowed the fluid to the rumen. It is rather remarkable that sheep 116 swallowed both tablets to the abomasum, although they have a fairly large size. The capsules in both cases passed into the forestomachs as would be expected. It is obviously out of the question to administer anthelmintics for oesophagostomiasis in the form of capsules or large pills, as they would almost invariably pass to the forestomachs where they will either disintegrate before passing on or they would be passed to the mouth in rumination and probably dropped by the animal.

#### TEST XV.

The sheep were kept from food and water for 28 hours. The intention was to see what effect starvation had on the abomasal contents and whether thirsty sheep would swallow water to the abomasum, as Wester found to be the case with cattle. Some of the sheep were dosed at the same time.

Sheep 120 and 121 received only salt and 5 seconds later  $Pb_3O_4$ . In 120 the ruminal contents were semi-fluid, and in 121 fluid. In both cases the abomasum contained about 50 c.c. fluid ingesta and the powder went to the rumen and a small quantity to the omasal groove.

Sheep 122 and 123 given each 2 litres water with Carmine by stomach tube. This went to the rumen and reticulum as expected. In 122 the abomasum contained a normal quantity of ingesta, in 123 it was almost empty.

Sheep 124 and 125 allowed to drink and killed 20 minutes later after dosing with salt and lead oxide. Both rumen fluid and abomasum about 40 c.c. fluid ingesta. Swallowed to abomasum and omasal groove. Apparently little or none of the water was swallowed to the abomasum.

Sheep 126 and 127 given salt to lick, then water to drink, then dosed with salt and lead oxide and killed. In 126 rumen contents semi-solid, 127 fluid and gas; both had about 40 c.c. fluid ingesta in abomasum. Powder swallowed to rumen in both cases. Here also the water apparently all went to the forestomachs.

Sheep 128 and 129 given each 2 litres water and much air by stomach tube and then dosed with salt and lead oxide. In 128 rumen contained fluid and gas, abomasum almost empty; swallowed powder to reticulum and small quantity to omasal groove. In 129 there was much gas in the forestomachs, abomasum and even the duodenum. The abomasum contained a small quantity of ingesta and the powder. This gives no definite indication whether gas in the rumen hinders closing of the groove. In sheep 129 the excessive amount of gas may have had an abnormal effect.

## TEST XVI.

Sheep kept from water 28 hours, dosed a level tablespoonful of salt 8.30 a.m., allowed to drink at 2 p.m. and all drank well. They were then dosed with salt and 5 seconds later with red lead oxide. The intention was to observe any possible factors other than those that were being controlled.

No.	Age.	Sex.	Concl.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
130.....	2	f	—	++	—	—	10	—	—	—
131.....	2	f	—	—	—	—	—	—	2	8
132.....	4	f	—	—	+	—	5	3	2	—
133.....	8	o	—	—	+	—	—	1	4	—
134.....	8	o	—	—	++	—	1	—	2	7
135.....	8	o	—	—	++	—	—	—	2	8
136.....	6	o	—	++	++	7	—	3	—	—
137.....	4	f	—	++	++	—	—	1	2	7
138.....	8	o	—	++	++	7	3	—	—	—
139.....	4	f	—	++	+	10	—	—	—	—
140.....	4	o	—	++	+	—	10	—	—	—
141.....	2	f	—	+	+	—	6	4	—	—

*Discussion.*—Four of the five sheep with fluid ruminal contents swallowed satisfactorily in spite of gas in three of them. One of six sheep with semi-fluid ruminal contents swallowed satisfactorily and one did not swallow; five had gas. The sheep with semi-solid ruminal contents swallowed to the rumen. These results again indicate that consistence of the ruminal contents is apparently important. Age had no influence, the older sheep swallowed even better than the younger ones. There were no factors that appeared to be important besides those that were taken into account.

## TEST XVII.

The object was to determine the effect of various stimulants and sedatives. The sheep were kept from water for 29 hours, dosed a level tablespoonful of salt at 8.30 a.m. and allowed to drink  $\frac{1}{2}$ -1 hour before treatment.

Sheep 142 and 143 received 0.5 gr. Atropine in 4 c.c. water per os and 1 minute later  $Pb_3O_4$ .

Sheep 144 and 145 received 2 gr. Cocaine in 4 c.c. water per os and 1 minute later  $Pb_3O_4$ .

Sheep 146 and 147 received 2 gm. Chloral hydrate in 5 c.c. water per os and 1 minute later  $Pb_3O_4$ .

Sheep 148 and 149 received 20 c.c. strong coffee per os and 1 minute later  $Pb_3O_4$ .

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Sheep 150 and 151 received 2 gm. moistened mustard per os and 5 seconds later  $Pb_3O_4$ .

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
142.....	2	f	33	—	+	5	5	—	—	—
143.....	6	f	33	—	+	—	3	2	—	—
144.....	2	f	33	+	+	—	3	—	7	—
145.....	2	f	33	++	—	—	1	3	2	4
146.....	4	f	33	++	—	—	5	3	2	—
147.....	4	f	33	++	+	—	—	—	2	3
148.....	2	f	33	—	+	—	10	—	—	—
149.....	6	o	33	++	+	5	3	2	—	—
150.....	8	o	33	++	+	4	4	2	—	—
151.....	2	f	33	++	—	—	10	—	—	—

*Discussion.*—Atropine acted as had been expected, but the number of sheep used is small. The results with the other drugs are difficult to explain, but the interval may have been too short.

## TEST XVIII.

Continuation of previous test. Sheep kept from water for 28 hours and allowed to drink  $\frac{1}{2}$ –1 hour before treatment.

Sheep 152 and 153 dosed with level teaspoonful sodium acetate and 5 seconds later  $Pb_3O_4$ .

Sheep 154–157 dosed with  $\frac{1}{2}$  gr. Atropine in 4 c.c. water, 1 minute later NaCl and 5 seconds later  $Pb_3O_4$ .

Sheep 158–160 dosed with 0.005 gm. strychnine sulphate in 4 c.c. water, 5 minutes later NaCl and 5 seconds later  $Pb_3O_4$ .

Sheep 161–162 dosed with level teaspoonful Calcium lactate and 5 seconds later  $Pb_3O_4$ .

Sheep 163–164 dosed with 1/6th gr. Physostigimine sulphate and 15 minutes later  $Pb_3O_4$ .

Sheep 165–166 dosed with 4 c.c. 6 per cent. Mustard suspension and 5 seconds later  $Pb_3O_4$ .

Sheep 167–168 dosed with 10 c.c. 5 per cent. solution of 40 per cent. nicotine and 30 seconds later  $Pb_3O_4$ .

Sheep 169–170 dosed with 2 gm. Tartar emetic in 300 c.c. water and 1 hour later  $Pb_3O_4$ .

Sheep 171–172 dosed with 2 gm. Tartar emetic in 1,500 c.c. water and 1 hour later  $Pb_3O_4$ .

Sheep 173-174 dosed with 3 gm. Barium chloride in 1,500 c.c. water and 1 hour later  $Pb_3O_4$ .

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
152.....	1	o	m	++	—	—	1	—	2	7
153.....	1	f	m	—	—	—	—	—	2	8
154.....	1	f	m	—	—	—	10	—	—	—
155.....	1	o	m	++	+	—	—	—	2	8
156.....	1	f	m	++	+	—	6	3	1	—
157.....	1	o	m	++	+	—	1	—	2	7
158.....	1	o	m	++	+	—	—	1	2	7
159.....	1	f	m	—	+	—	—	10	—	—
160.....	1	f	m	—	—	—	1	1	2	6
161.....	1	m	m	—	—	—	5	4	1	—
162.....	1	f	m	—	—	—	5	4	1	—
163.....	1	f	f	++	—	4	5	—	1	—
164.....	1	f	f	—	—	—	5	5	—	—
165.....	1	f	m	—	+	—	6	4	—	—
166.....	1	f	m	++	—	—	6	4	—	—
167.....	1	f	f	++	+	—	5	4	1	—
168.....	1	f	f	++	—	—	5	3	2	—
169.....	1	f	f	++	+	4	4	2	—	—
170.....	1	f	f	++	+	—	5	4	1	—
171.....	4	o	f	+	—	—	5	4	1	—
172.....	4	o	f	—	—	—	4	3	3	—
173.....	4	o	f	++	—	—	6	4	—	—
174.....	4	o	f	++	—	—	3	5	2	—

*Discussion.*—Sodium acetate acted well as expected. Atropine is not always able to counteract the stimulation of salt, or the route taken by the powder is not influenced by these factors only. The latter view gains support from the other results which indicate that the most important factor has not yet been discovered.

## TEST XIX.

In order to test again the influence of starvation sheep 175-180 were kept from food and water and sheep 181-186 from water only for 28 hours. All were allowed to drink  $\frac{1}{2}$ -1 hour before dosing, but they were apparently not very thirsty, as only 175-177 drank well and a few of the others drank a little. They were dosed in the usual way with salt and 5 seconds later red lead oxide.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
175.....	6	o	gg gg	++	+	—	—	—	2	8
176.....	8	o	gg gg	—	+	—	—	—	2	8
177.....	8	o	gg gg	++	+	—	6	4	—	—
178.....	6	o	—	—	+	—	—	—	2	8
179.....	8	o	gg gg	+	+	—	1	—	2	7
180.....	8	o	gg gg	++	—	—	8	—	2	—
181.....	4	o	gg gg	++	—	—	8	—	2	—
182.....	2	f	gg gg	++	+	6	—	4	—	—
183.....	6	o	gg gg	++	—	—	—	—	4	6
184.....	6	o	gg gg	++	+	—	4	3	3	—
185.....	8	o	gg gg	++	+	—	—	—	2	8
186.....	6	o	gg gg	+	+	—	4	3	3	—

*Discussion.*—These results appear to be in favour of starvation, but when they are taken together with those of Test XV, the findings are not conclusive. Again the presence of gas does not seem to affect the result.

## TEST XX.

The foregoing tests, as well as Wester's work, indicate strongly that sodium salts stimulate closing of the oesophageal groove. It was consequently thought that solubility of the particular salt used may be important, since greater solubility should mean more rapid and intensive action on the vagus endings. For this purpose the sheep were kept from water for 29 hours and allowed to drink about half an hour before treatment. All except 199-210 drank. A level teaspoonful of each salt was administered 5 seconds before the red lead oxide in the usual way.

Sheep 187-190 received sodium fluoride, sol. at 30° C about 3/100 gm. H<sub>2</sub>O.

Sheep 191-194 received sodium citrate, sol. at 30° C about 11·8/100 gm. H<sub>2</sub>O.

Sheep 195-193 received sodium bicarbonate, sol. at 30° C about 11·1/100 gm. H<sub>2</sub>O.

Sheep 199-202 received sodium hydrogen phosphate sol. at 30° C about 22/100 gm. H<sub>2</sub>O.

Sheep 203-206 received sodium sulphate, sol. at 30° C about 40·8/100 gm. H<sub>2</sub>O.

Sheep 207-210 received sodium acetate, sol. at 30° C about 54·5/100 gm. H<sub>2</sub>O.

Sheep 211-214 received sodium thiosulphate, sol. at 30° C about 78/100 gm. H<sub>2</sub>O.

Sheep 215-218 received sodium nitrate, sol. at 30° C about 95/100 gm. H<sub>2</sub>O.

Sheep 219-222 received sodium bromide, sol. at 30° C about 97·3/100 gm. H<sub>2</sub>O.

Sheep 223-225 received sodium salicylate, sol. at 30° C about 100/100 gm. H<sub>2</sub>O.

Sheep 226-228 received sodium chlorate, sol. at 30° C about 113/100 gm. H<sub>2</sub>O.

Sheep 229-231 received sodium iodide, sol. at 30° C about 190/100 gm. H<sub>2</sub>O.

Sheep 232-234 received sodium chloride, sol at 30° C about 36/100 gm. H<sub>2</sub>O.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Month.	Rumen.	Retic.	Om. gr.	Abom.
187.....	6	o	gg	—	+	—	8	2	—	—
188.....	6	o	gg	±	—	—	8	2	—	—
189.....	6	f	gggg	±	—	—	1	1	2	6
190.....	6	o	gggg	—	—	—	8	2	—	—
191.....	8	o	gggg	+	—	—	8	2	—	—
192.....	6	o	gggg	±	—	—	—	—	3	7
193.....	6	o	gggg	+	—	—	7	2	1	—
194.....	6	o	gggf	±	—	—	8	2	—	—
195.....	6	o	gf	—	—	—	8	2	—	—
196.....	6	f	gg	±	—	—	7	2	1	—
197.....	6	o	ggf	±	—	—	8	2	—	—
198.....	6	o	gg	—	—	5	3	2	—	—
199.....	4	o	gg	±	—	—	8	2	—	—
200.....	8	o	gggg	±	—	9	1	—	—	—
201.....	4	o	ggf	+	—	—	8	2	—	—
202.....	8	o	gg	±	—	—	1	1	3	5
203.....	6	f	ggf	—	—	—	8	2	—	—
204.....	6	o	gg	—	—	—	—	10	—	—
205.....	6	o	Hgg	±	—	5	5	—	—	—
206.....	6	o	g	±	—	5	5	—	—	—

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
207	6	o	f	±	—	—	1	—	4	5
208	8	o	f	±	—	—	8	2	—	—
209	6	o	f	±	—	9	1	—	—	—
210	6	o	f	±	—	—	—	—	2	8
211	8	o	f	±	—	—	7	2	1	—
212	6	o	f	—	—	10	—	—	—	—
213	6	o	f	—	—	—	7	2	1	—
214	8	o	f	—	—	3	3	4	—	—
215	4	o	f	—	—	4	3	—	—	3
216	6	o	f	—	—	—	10	—	—	—
217	4	o	f	—	—	—	7	3	—	—
218	6	o	f	—	—	6	4	—	—	—
219	6	o	f	—	—	10	—	—	—	—
220	8	o	f	—	+	—	2	2	3	3
221	6	o	f	—	—	—	—	10	—	—
222	6	o	f	—	—	—	1	—	3	6
223	6	o	f	±	—	—	7	2	1	—
224	6	o	f	—	—	5	—	—	2	3
225	6	o	f	±	—	—	3	2	4	1
226	6	o	f	—	—	—	10	—	—	—
227	8	o	f	—	—	9	—	1	—	—
228	6	o	f	—	—	—	7	2	1	—
229	6	o	f	+	—	—	8	2	—	—
230	6	o	f	—	—	—	—	—	2	8
231	8	o	f	—	—	10	—	—	—	—
232	6	o	f	+	—	—	—	1	2	7
233	6	o	f	—	—	9	1	—	—	—
234	6	o	f	—	+	—	6	2	2	—

*Discussion.*—The results show nothing in favour of any particular sodium salt, nor, in fact, do they prove the value of sodium salts as stimulants. At least as good results might be expected without any stimulation at all.

## TEST XXI.

The object was to test strong alkaline solutions with variation of the interval at the same time. Sheep kept from water for 39 hours, then watered 1— $\frac{1}{4}$  hour before dosing. Sheep 235 and 236 dosed with 4 c.c. N/10 NaOH and lead oxide after 5 seconds. Sheep 237 and 238 dosed with 4 c.c. N/10 NaOH and lead oxide immediately. Sheep 239 and 240 dosed with conc. NaCO<sub>3</sub> sol. and lead oxide after 5 seconds. Sheep 241 and 242 dosed with conc. NaCO<sub>3</sub> sol. and lead oxide immediately. Sheep 243 and 244 dosed with NaCl and lead oxide after 5 seconds. Sheep 245 and 246 dosed with NaCl and lead oxide immediately.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
235	4	o	f	±	—	—	10	—	—	—
236	6	o	f	±	—	—	—	—	3	7
237	6	o	f	±	+	—	10	—	—	—
238	8	o	m	±	—	—	1	—	3	6
239	6	o	p	—	+	—	10	—	—	—
240	4	o	f	±	—	—	—	—	3	7
241	4	o	f	±	—	—	10	—	—	—
242	2	o	f	±	—	—	10	—	—	—
243	4	o	f	±	—	—	9	1	—	—
244	4	o	f	±	—	—	6	4	—	—
245	8	o	f	±	—	—	—	—	4	6
246	4	o	f	±	—	—	—	—	9	1

*Discussion.*—Again there is no proof that sodium salts act as stimulants or, at least, that stimulation of the vagus is the main factor causing the groove to close.

## TEST XXII.

Similar to the previous test. At the same time the question of pleasant or unpleasant taste was touched, because it was thought that, if sodium chloride was the most active sodium salt, there must be some reason for this and cattle and sheep generally like salt. The sheep were kept from water for 30 hours and watered 1- $\frac{1}{4}$  hour before treatment.

Sheep 247 and 248 dosed with 4 c.c. hot conc. NaCl sol. and lead oxide after 5 seconds.

Sheep 249 and 250 dosed with 4 c.c. hot conc. NaCl sol. and lead oxide immediately.

Sheep 251 and 252 dosed with 4 c.c. hot conc. NaCl sol. and mixed with lead oxide.

Sheep 253 and 254 dosed with 4 c.c. cold conc. NaCl sol. mixed with lead oxide.

Sheep 255 and 256 dosed with 4 c.c. cold conc. NaCl sol. and lead oxide + aniseed, immediately.

Sheep 257 and 258 dosed with 4 c.c. cold conc. NaCl sol. and lead oxide + CS<sub>2</sub>, immediately.

The hot solutions had a temperature of about 60° C.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
247.....	4	o	m	±	—	—	7	2	1	—
248.....	4	o	m	+	—	—	7	3	—	—
249.....	2	o	f	±	—	—	—	4	6	—
250.....	6	o	m	+	—	—	5	3	2	—
251.....	6	o	m	+	—	—	10	—	—	—
252.....	2	o	f	+	—	—	1	—	8	1
253.....	4	o	f	±	—	—	6	4	—	—
254.....	4	o	m	+	—	—	9	1	—	—
255.....	4	o	m	±	—	—	6	4	—	—
256.....	4	o	m	±	—	—	7	3	—	—
257.....	4	o	m	±	—	—	1	—	3	6
258.....	4	o	m	±	—	—	5	4	—	1

*Discussion.*—The hot salt solution had no particular advantage. If the taste plays any part an unpleasant taste would be preferable according to these results. Perhaps a distinction must be made between the taste of the stimulant and that of the drug to be administered.

## TEST XXIII.

In view of the results of Sprehn quoted above, the following test was made. Sheep kept from water for 30 hours, then watered 1 hour before treatment.

Sheep 259 and 260 dosed with salt and 1 second later a level teaspoonful of kaffircorn.

Sheep 261 and 262 dosed with salt and 1 second later a level teaspoonful of lead shot.

Sheep 263 and 264 dosed with level teaspoonful of lead shot only.

The kaffircorn has almost round seeds, 3-4 mm. in diameter and the shot was about the same size. The kaffir corn seeds had been stained in eosin to make them conspicuous in the stomach contents.

No.	Age.	Sex.	Cond.	R. cons.	Gas.	Mouth.	Rumen.	Retic.	Om. gr.	Abom.
259.....	4	o	++	+	—	—	10	—	—	—
260.....	4	o	++	+	—	—	10	—	—	—
261.....	4	o	++	+	—	—	10	—	—	—
262.....	4	o	++	++	—	—	10	—	—	—
263.....	4	o	++	++	—	—	10	—	—	—
264.....	4	o	+	++	—	—	—	—	5	5

*Discussion.*—These results indicate that particles of this size will only exceptionally pass to the abomasum, even after stimulation with salt.

### SUMMARY AND CONCLUSIONS.

The possibility of dosing into the abomasum by administering various materials, especially inert powders, after stimulating the oesophageal groove to close, was investigated and the results obtained with 264 sheep are recorded.

The work of Wester was taken as a basis and numerous variations were made in the preparation of the animals, the method of administration and the materials administered. The results are of such a nature that practically no conclusions can be drawn. It is possible that soluble sodium salts stimulates the vagus endings in the pharynx and may thus cause reflex closure of the oesophageal groove, but other important factors, which have not been elucidated, frequently counteract such stimulation or the reflex. It is possible that semi-solid nature of the ruminal contents and the presence of gas in the rumen and reticulum are such adverse factors.

On the whole, the age and the condition of the sheep did not appear to affect the results.

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