A STUDY OF THE IMPORTANCE, OVERWINTER SURVIVAL, AND GEOGRAPHICAL DISTRIBUTION OF INTERNAL PARASITES OF SHEEP IN MANITOBA

BY WILLIAM EWERT REMPEL

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A STUDY OF THE IMPORTANCE, OVERWINTER SURVIVAL, AND GEOGRAPHICAL DISTRIBUTION OF INTERNAL PARASITES OF SHEEP IN MANITOBA

A number of natural factors favor the production of sheep in Manitoba. Large tracts of cheap land, unsuited for more intensive types of agricultural endeavor, appear ideal for sheep-raising. These areas provide sufficient forage for large flocks of sheep that can be kept over winter at low cost. The usual practice is to provide low-cost, open-type sheds for shelter, as sheep do very well in such quarters. This type of shelter also requires little in the way of labor that would be necessary in a more elaborate system of housing.

The prices of sheep and sheep products in recent years have been consistently higher than previously, and in view of the smaller amount of labor required for sheep raising than for other types of agriculture, one might reasonably have anticipated a substantial increase in the sheep population during the war. Also favoring an expansion of sheep population is the low provincial incidence or relative absence of bacterial, virus and protozoan diseases such as anthrax, foot-and-mouth disease, looping ill, scrapie and braxie(59).

Despite all these natural advantages, the sheep industry in Manitoba has not flourished. The Dominion Government's request for a 25 percent increase in sheep production during the war was not met, although in Manitoba there was some increase in the number of sheep kept during this period. This increase in Manitoba constituted a shift of sheep population rather than a real increase for the whole Dominion; the sheep population of Canada in 1937 was about the same as in 1871(59). The trend has been for the sheep population to increase in an area for a time, and then to shift to some other part of the country, mostly from the east to the west. The evidence that the increase in Manitoba was due, in part at least, to such a shift in population rests on the figures of the Provincial Department of Agriculture, which show that the sheep population in Manitoba reached the peak figure of 327,000 in 1943, but dropped to 319,000 in 1944(38).

It has been demonstrated that in Eastern Canada, parasitic diseases of sheep were taking a tremendous toll (59). Till recently it had been assumed that the climate in Manitoba was too dry and the winters too long and severe for sheep to acquire heavy infestations of internal parasites. This proved to be a fallacy, when, during the last number of years, many sheep raisers were unable to market their lambs in the fall because of stunted growth.

Invariably when such stunted and emaciated animals were examined, they were found to harbour a great number of intestinal and stomach parasites. These preliminary examinations suggested that internal parasites are the limiting factor in sheep production in Manitoba.

When the fact that internal parasites constituted the limiting factor in sheep production was demonstrated, it was decided that a general survey should be conducted to determine the species of parasites that occur here. There are a variety of phases of parasitism that could have been studied, such as the host-parasite relationship, pathogenicity, modes of infection and life cycles, but it was the intention of the writer to gather information on those phases that would be of immediate economic benefit to the sheep industry in Manitoba. With this view in mind, special attention was paid to the factors that would assist the adoption of adequate control measures. The incidence and geographical distribution of sheep parasites was determined in order to prove to the practical man that a parasitic problem exists.

When it was once determined that parasitism was the limiting factor in sheep production, a study of the modes of spreading parasitic infections became a necessity. It was deemed essential that a study of the ages and conditions of sheep that are most favorable to parasitic infestations be studied also. In order to give practical value to the study of this important problem, a study of the symptoms, diagnosis and pathogenicity of parasitic infections was included in the present survey.

It is the writer's contention that when information regarding all the salient points of parasitism in sheep is placed in the hands of extension workers, an intelligent campaign against the biggest hazard to the sheep industry can be launched and brought to a favorable conclusion. With this view in mind, the different phases of the parasite problem of sheep in Manitoba were studied by the writer from May 1944 to September 1945. The results of this study are presented in the following report.

MATERIALS AND METHODS

In the summer of 1944 some information on sheep parasites was gathered, mainly from tests conducted on the flock at the University of Manitoba but also from some of the flocks adjacent to the Winnipeg area. The following winter was spent in testing the overwinter survival of the free-living stages of *Haemonchus contortus*, the large stomach worm of sheep. This species proved to be the most common and widely distributed parasite of sheep in Manitoba.

During the summer of 1945 a survey was conducted to determine the types and relative degree of infestation of the helminth parasites of sheep in Manitoba. This included a study of the incidence and geographical distribution of the different species.

In all a total of 96 farms in 15 different areas in the province were surveyed. The number of farms to be visited in each district was calculated roughly according to the total sheep population in that district, relative to the total sheep population in the province.

An effort was made to take uncontaminated faecal samples from 10 different sheep on each of the farms visited. This number could not be rigidly adhered to in the field, but a total of 868 individual faecal samples were examined from the 96 farms, or the equivalent of just over 9 sheep examined on each of the farms visited.

Although this number is a small percentage of the total sheep population in Manitoba, the random selection of the farms and animals should tend to give a moderately accurate picture of sheep parasitism in this province.

DIVISION OF DISTRICTS

The data gathered during the survey has been divided into 15 separate districts. These divisions follow from the fact that the Manitoba Department of Agriculture has grouped together certain adjoining municipalities to comprise Agricultural Representative districts. It was by the assistance of the Agricultural Representatives that the writer was enabled to traverse the survey area, and the data have been kept segregated into these districts to facilitate their interpretation.

The data are based mainly on the helminth ova found and identified in the faecal samples. Post mortem examinations were conducted whenever the opportunity afforded, so that the actual specimens could be taken and specifically identified. The ova were identified according to Kates and Shorb(33). Adult nematodes were cleared in the laboratory and their identity established according to the keys set out by Yorke and Maplestone(68). The cestodes required staining as well as clearing before they could be specifically differentiated. This was accomplished with the aid of Monnig's text on that topic(41).

Over the two years of the survey, 16 post mortem examinations were conducted in the field. The viscera of 5 sheep from local packing plants were also examined, as well as the viscera of 6 sheep sent in to the Provincial Animal Pathology Laboratory for post mortem.

The faecal samples were taken either directly from the rectum of the animal, or from uncontaminated, freshly dropped excretions. The faecal samples were then placed in small consecutively numbered bottles and preserved in 10 percent formalin or by means of cotton wadding soaked in ortho-dichloro-benzine(67). The preservative prevented the ova from developing enroute to the laboratory but left their ability to rise to the surface of a concentrated salt solution unchanged.

Pertinent information on the flock management was collected from each farm by filling in a routine questionnaire. The questions asked dealt with the type and size of farm, size and management of the flock, mortality losses, anthelmintic medication, and general practice.

EGG-COUNTING TECHNIQUE

A modified dilution-flotation technique was employed in the laboratory to determine the number of helminth eggs the faeces contained per gram(66). Ten grams of faeces were weighed from each sample and placed in a half-pint bottle.

Water was added to a filed mark at the 150 cc. level. The solid faecal particles were broken up by means of a glass rod, and mixed with an electric mixer for one and a half minutes so as to get an even suspension(36).

A portion of the suspension was then poured through a strainer into a glass beaker. A 0.5 cc. sample of this suspension was drawn up into a 1.0 cc. syringe, and 0.5 cc. of a saturated sodium chloride solution was also drawn into the syringe. The two solutions were then mixed by means of an air bubble drawn into the barrel of the syringe(66). Three 0.15 cc. samples were then placed in a special counting slide for examination under the microscope. These slides were left undisturbed for several minutes. During this time the helminth ova floated to the upper surface of the counting chamber, while the faecal debris sank to the bottom. In this way the ova were gathered in a relatively small area, free from debris, and could be identified quickly and easily. The number of each parasitic species for the triplicate count from each sheep was averaged and recorded on separate, numbered cards corresponding to the number designated for the sheep and farm at the time the sample was taken. The total number of eggs per gram of all the parasitic species present in particular sheep was also entered on the card.

No attempt was made to eliminate the variation in egg-count due to differences in the moisture content of the faecal sample because it has been found that the day to day and sample to sample variation can not be eliminated even by dry-basis counts, and the extra work of drying the faecal samples was avoided(44). The writer is also aware that there are seasonal variations in the egg-counts of nematodes(39). As the present data are not being used to draw conclusions and comparisons from the actual numbers of ova present, the seasonal factor was also disregarded. The present egg-count data were used mainly to determine the species of parasite present by differentiation of their ova.

During the course of the survey, 13 different genera of nematodes and 2 genera of cestodes were found to be present in Manitoba sheep. These were specifically identified and their classification is listed below.

ZOOLOGICAL CLASSIFICATION

OF THE HELMINTH PARASITES OF SHEEP IN MANITOBA

CLASS: NEMATODA — ORDER: EUNEMATODA

I. SUPERFAMILY: STRONGYLOIDEA

A. Family: Trichostrongylidae — Subfamily: Trichostrongylinae

Genera:
1. Haemonchus
2. Ostertagia
3. Cooperia
4. Trichostrongylus
5. Nematodirus
6. Mecistocirrus

B. Family: Strongylidae — Subfamily: Oesophagostominae

Genera:
1. Oesophagostomum
2. Chabertia

C. Family: Ancylostomidae — Subfamily: Necatorinae

Genus: 1. Bunostomum

D. Family: Metastrongylidae — Subfamily: Metastrongylinae

Genus: 1. Dictyocaulus

II. SUPERFAMILY: TRICHUROIDEA

A. Family: Trichuridae

Subfamily: Trichurinae

Genus: 1. Trichuris

Subfamily: Capillarinae

Genus: 1. Capillaria

III. SUPERFAMILY: RHABDIASOIDEA

A. Family: Rhabdiasidae

Genus: 1. Strongyloides

CLASS: CESTODA

SUPERFAMILY: TAENIOIDEA

Family:Anoplociphalidae Subfamily:Anoplocephalinae

Genus: Moniezia

M. expansa

M. benedeni

Family:Taeniidae

Genus: Taenia

T. hydatigena (*Cysticercous tenuicollis*)

INCIDENCE OF PARASITISM

Table I shows the proportions of Manitoba sheep and flocks that are parasitized. The table is arranged so that a comparison can be made between the various districts concerned.

From the table it can be seen that parasitism is particularly severe in those districts that are located in the Interlake area and east of the Red River. The Interlake area refers to that portion of Manitoba situated between Lake Winnipeg and Lake Manitoba. For this whole area, comprised of the first five districts listed in the table, at least 40 percent of all sheep examined showed evidence of parasitism. This is considerably higher than the 28 percent for the province as a whole, or the less than 18 percent for the part of the province outside of the Interlake area and the portion east of the Red River.

The table also shows a high percentage of parasitised sheep for districts such as Russell, Carman, and Elkhorn, which are outside of the parasitological area. In fairness to these areas it must be said that the figures in the table indicate a higher incidence of parasitism than the actual for these districts. This results from the fact that only two farms were selected because parasitism was suspected, so that the species occurring in the particular area could be determined.

The Shoal Lake area shows a relatively high incidence of parasitism, but the results from this area are weighted by a particularly large flock in the Birtle district. The owner of this flock buys a large number of ewes from packing plants outside of Manitoba, and a high percentage of these animals are parasitized as shown by faecal egg counts and visible symptoms. This parasitism decreases in severity as the season progresses, because the animals have access to an abundance of brome grass pasture over a large area of hilly land with a good water supply. This flock was checked twice during the summer of 1945, and the degree of parasitism was much less at the time of the second visit.

The area east of the Red River and the Interlake country can be called the parasitological centre of Manitoba as far as sheep are concerned. This area contains more than one third of the total sheep population of Manitoba and practically every farm has some parasitised animals.

Table I also shows a low incidence of parasitism for the area around St. Pierre. This area is actually more heavily parasitized than the table would indicate. While faecal samples were taken from only three flocks in this area, a number of other farms in the district were visited and several flock owners had just gone out of sheep

TABLE I

INCIDENCE OF PARASITISM IN MANITOBA SHEEP

District	No. of Farms Visited	No. of Farms Parasitized	No. of Sheep Examined	No. of Sheep Parasitized	% of Sheep	% of Farms
Eriksdale	11	11	90	54	60.0%	100.0%
Seven Sisters	4	4	34	15	44.1	100.0
Selkirk	4	4	21	12	57.1	100.0
Teulon	16	15	160	58	36.2	93.8
Vita	10	8	96	22	22.9	80.0
Minnedosa	10	6	100	22	22.0	60.0
Russell	2	2	13	6	46.2	100.0
Carman	2	2	20	5	25.0	100.0
St. Pierre	3	2	30	3	10.0	60.0
Pilot Mound	5	3	50	7	14.0	40.0
Boissevain	4	1	40	1	2.5	25.0
Dauphin	11	4	90	6	6.7	36.4
Swan River	8	6	61	9	14.8	75.0
Shoal Lake	4	4	40	13	32.5	100.0
Elkhorn	2	1	23	11	47.8	50.0
Total	96	73	868	244	28.1%	76.0%

production. While some of these owners claimed that marauding dogs had forced them out of business, others described symptoms of parasitic diseases as the cause.

PREVALENCE OF CERTAIN GENERA

Besides determining the different parasites that occur in Manitoba sheep, and the incidence of these parasites, knowledge of what genera are most widespread and occur most frequently is important in planning control measures. Table II shows the regularity with which certain parasites occur on different farms.

Haemonchus is the most common parasite of sheep in Manitoba. It occurs in more sheep than any other parasite, and can be found in more flocks.

Ostertagia, Chabertia, Trichostrongylus, and Bunostomum are all found in a large percentage of the flocks. The difference in their incidence may be entirely seasonal, but in any case they are sufficiently widely distributed to cause trouble over a wide area.

The data with regard to Moniezia are not very accurate because this parasite can sometimes be found in animals at post mortem when no eggs appeared in the faeces. In the life cycle of this genus the gravid segments pass out in the faeces, rather than the eggs being shed in the host and mixed with the faeces. The fact that eggs of this tapeworm were found in faecal samples of 20 percent of the flocks tested, indicates that Moniezia is very common in Manitoba sheep.

The other genera occur less frequently. Nematodirus

TABLE II

PERCENTAGE OF SHEEP INFECTED WITH VARIOUS GENERA

AS SHOWN BY FAECAL EGG-COUNTS

Parasitic Genera	No. of Sheep Infected	% of Tested Sheep	No. of Flocks Found in	% of Flocks Tested	Average Egg-count per gram
Haemonchus	103	11.86	50	52.08	312.2
Ostertagia	69	7.94	38	39.58	212.2
Chabertia	51	5.87	33	34.37	198.0
Trichostrongylus	45	5.18	29	30.20	147.0
Bunostomum	57	6.56	26	27.08	109.3
Moniezia	27	3.11	20	20.83	454.0
Cooperia	18	2.07	13	13.54	111.7
Strongyloides	17	1.95	10	10.41	67.6
Nematodirus	12	1.38	6	6.25	194.4
Oesophagostomum	6	.69	6	6.25	107.0
Capillaria	1	.11	1	1.04	60.0

occurs only in certain areas, as does Cooperia.

Strongyloides was found to be widely distributed but only a few sheep in any flock were found to harbour this parasite.

Oesophagostomum occurs only in one locality, and this accounts for the extremely small number of sheep found to be infected with it. In the south-eastern part of Manitoba, however, it was found on 6 out of the 10 farms visited.

Capillaria was found in a single animal only, and here the infection was slight.

Although evidence of parasitism was found in 75 per-cent of the flocks examined (Table I), no one species is found in all these flocks, and some species occur very rarely.

The number of worm eggs found per gram of faeces is not particularly high for any of the genera that occur, but of course this varies with the season of the year(39). On the other hand, if only a small percentage of these eggs reach the infective stage and gain entrance to the host, a parasitic problem can result in a short while, because some of these species can reproduce in the short space of three weeks.

NUMBER OF GENERA PER SHEEP

For many years little thought was given to parasitism as a problem in sheep production in Manitoba. When outbreaks occurred, however, in certain areas the trend of thought changed, and some people connected with the sheep industry now have the opinion that parasitism is as important a problem here as in the eastern provinces.

In Eastern Canada it was found that the average number of genera harboured by individual sheep was eight(21). To show a comparison between the two regions Table II was obtained from data of 244 infected sheep in Manitoba. The table is broken down into 15 component parts for that portion of the province that was surveyed. In every district except two there were more animals infected with a single species than with more. In these two districts the number of animals infected with two genera and with one genus were equal.

These results show that the parasitic hazard here is not nearly so great as it is in Eastern Canada. Different parasitic genera are sufficiently well distributed in the province, however, to cause serious damage when conditions for their rapid reproduction and dissemination are suitable.

TABLE III

NUMBER OF GENERA OF PARASITES FOUND PER ANIMAL IN 244

INFECTED MANITOBA SHEEP

NO. OF GENERA	NO. OF ANIMALS INFECTED	PERCENTAGE OF ANIMALS INFECTED
1	130	53.2%
2	70	28.7
3	21	8.6
4	14	5.7
5	7	2.8
6	--	0.0
7	1	.4

NUMBER OF GENERA PER ANIMAL BY DISTRICTS

DISTRICT	TOTAL GENERA FOUND	TOTAL SHEEP INFECTED	NO. OF GENERA	NO. OF ANIMALS	PERCENTAGE ANIMALS INFECTED
Eriksdale	8	54	1	21	38.9%
			2	19	35.2
			3	10	18.5
			4	4	7.4
Seven Sisters	7	15	1	11	73.3
			2	1	6.7
			3	1	6.7
			4	2	13.3
Selkirk	11	12	1	6	50.0
			2	2	16.7
			3	--	----
			4	2	16.7
			5	1	8.3
			6	--	----
			7	1	8.3
Teulon	10	58	1	25	43.1
			2	23	39.6
			3	4	6.8
			4	3	5.1
			5	3	5.1

NUMBER OF GENERA PER ANIMAL BY DISTRICT (cont.)

DISTRICT	TOTAL GENERA FOUND	TOTAL SHEEP INFECTED	NO. OF GENERA	NO. OF ANIMALS	PERCENTAGE ANIMALS INFECTED
			1	15	68.1%
Vita	10	22	2	5	22.7
			3	1	4.5
			4	1	4.5
			1	16	72.7
Minnedosa	5	22	2	4	18.1
			3	1	4.5
			4	1	4.5
			1	3	50.0
			2	--	----
Russel	6	6	3	1	16.7
			4	1	16.7
			5	1	16.7
			1	4	80.0
			2	--	----
Carman	10	5	3	--	----
			4	--	----
			5	1	20.0
St. Pierre	3	3	1	3	100.0
Pilot			1	5	71.4
Mound	6	7	2	2	28.6
Boissevain	1	1	1	1	100.0
			1	4	44.4
Swan River	8	9	2	4	44.4
			3	1	11.1
			1	9	69.1
Shoal Lake	6	13	2	3	23.0
			3	1	7.9
			1	5	45.4
			2	4	36.4
Elkhorn	6	11	3	1	9.0
			4	--	----
			5	1	9.0
Dauphin	7	6	1	3	50.0
			2	3	50.0

GEOGRAPHICAL DISTRIBUTION OF PARASITIC GENERA

There is a wide variety of environmental factors in Manitoba. Such factors as rainfall, temperature, soil type and vegetation obviously must have an effect on that part of a parasite's life cycle that is spent outside of the host. Because of these variations from area to area it was thought desirable to determine the geographical distribution of the parasites that occur here, having in mind the possibility of exposing some environmental factor or factors specially suitable or unsuitable for the propagation of certain species.

In order to be able to read off quickly the genera that occur in a particular area, all the parasitic genera that were detected in Manitoba sheep are listed in Figure I under the Municipality in which the genera were found. This figure also shows the Municipalities that comprise the various districts mentioned earlier in this report.

Map I shows the geographical distribution of the genera in the family Trichostrongylidae. As a group these are the most common parasites of sheep in Manitoba. From the map it can not be said that the Trichostrongyles show any definite pattern in their distribution. It can be seen however, that they are widely distributed, and that they are particularly well represented in the Interlake country.

A combination of factors is probably responsible for the higher incidence of Trichostrongyles in this area. The soil in this region is practically all of the high lime type(18). This may be a factor favoring the development of the free-living stages of nematode parasites, although no definite proof of this exists.

FIGURE I

PARASITIC GENERA OF SHEEP PARASITES FOUND IN MANITOBA BY DISTRICT AND MUNICIPALITY

ERIKSDALE:

Woodlea: Haemonchus, Bunostomum & Strongyloides.

Siglunes: Haemonchus, Bunostomum, Trichostrongylus, Ostertagia & Strongyloides.

Coldwell: Haemonchus, Bunostomum, Trichostrongylus, Ostertagia, Strongyloides, Cooperia, Moniezia & Dictyocaulus.

Eriksdale: Haemonchus, Bunostomum, Trichostrongylus, & Strongyloides.

SEVEN SISTERS:

Lac-du-Bonnet: Haemonchus, Bunostomum, Chabertia, Trichostrongylus, Dictyocaulus.

Whitemouth: Haemonchus, Bunostomum, Chabertia, Ostertagia, Trichostrongylus.

Springfield: Haemonchus, Chabertia, & Strongyloides.

SELKIRK:

St. Andrews: Haemonchus, Ostertagia, Cooperia.

Brokenhead: Haemonchus, Ostertagia, Bunostomum, Chabertia, Trichostrongylus, Moniezia, Cooperia, Strongyloides, Dictyocaulus & Trichuris.

St. Clements: Haemonchus, Chabertia, Bunostomum, Moniezia, Cooperia, Ostertagia, Dictyocaulus.

TEULON:

Rockwood: Haemonchus, Chabertia, Bunostomum, Moniezia, Ostertagia, Cooperia, Trichostrongylus.

Bifrost: Haemonchus, Chabertia, Trichostrongylus, Ostertagia, Cooperia, Bunostomum, Moniezia, Strongyloides, Trichuris & Nematodirus.

Gimli: Haemonchus, Ostertagia, Chabertia, Trichostrongylus, Strongyloides, Bunostomum.

Kreuzberg: Haemonchus.

Armstrong: Chabertia, Haemonchus, Bunostomum, Ostertagia.

GEOGRAPHIC DISTRIBUTION OF PARASITIC GENERA (cont'd)

VITA:

Stuartburn: Haemonchus, Trichostrongylus, Chabertia, Bunostomum, Oesophagostomum, Moniezia, Strongyloides, Ostertagia.

Franklin: Ostertagia, Haemonchus, Moniezia, Oesophagostomum, Chabertia.

Piney: Oesophagostomum, Moniezia.

Sprague: Dictyocaulus, Trichstrongylus, Chabertia, Oesophagostomum, Trichuris.

MINNEDOSA:

Odanah: Ostertagia.

Saskatchewan: Haemonchus.

Minto: Haemonchus, Moniezia, Trichostrongylus, Ostertagia, Nematodirus.

Clanwilliam: Moniezia, Ostertagia.

RUSSEL:

Russell: Haemonchus.

Shellmouth: Haemonchus, Ostertagia, Chabertia, Trichostrongylus, Moniezia.

CARMAN:

Grey: Strongyloides, Bunostomum, Haemonchus, Chabertia, Trichostrongylus, Ostertagia, Dictyocaulus, Cysticercus & Trichuris.

Dufferin: Cooperia, Haemonchus.

ST. PIERRE:

De-Salaberry: Moniezia, Bunostomum, Haemonchus.

PILOT MOUND:

Louise: Haemonchus, Chabertia, Nematodirus.

Argyle: Ostertagia, Moniezia, Chabertia.

Pembina: Haemonchus, Trichostrongylus.

Roblin: 000000

GEOGRAPHIC DISTRIBUTION OF PARASITIC GENERA (cont'd)

BOISSEVAIN:

Morton: 000000

Turtle Mountain: 000000

Riverside: 000000

Whitewater: Ostertagia.

DAUPHIN:

St. Rose: Trichostrongylus, Ostertagia, Moniezia, Bunostomum.

Dauphin: 000000

Ethelbert: Haemonchus, Nematodirus, Ostertagia, Chabertia.

SWAN RIVER:

Swan River: Chabertia, Trichostrongylus, Ostertagia, Bunostomum.

Minitonas: Chabertia, Ostertagia, Dictyocaulus, Bunostomum, Moniezia, Cysticercus.

Unorganized: Chabertia, Haemonchus, Nematodirus, Ostertagia, Trichostrongylus, Capillaria.

SHOAL LAKE:

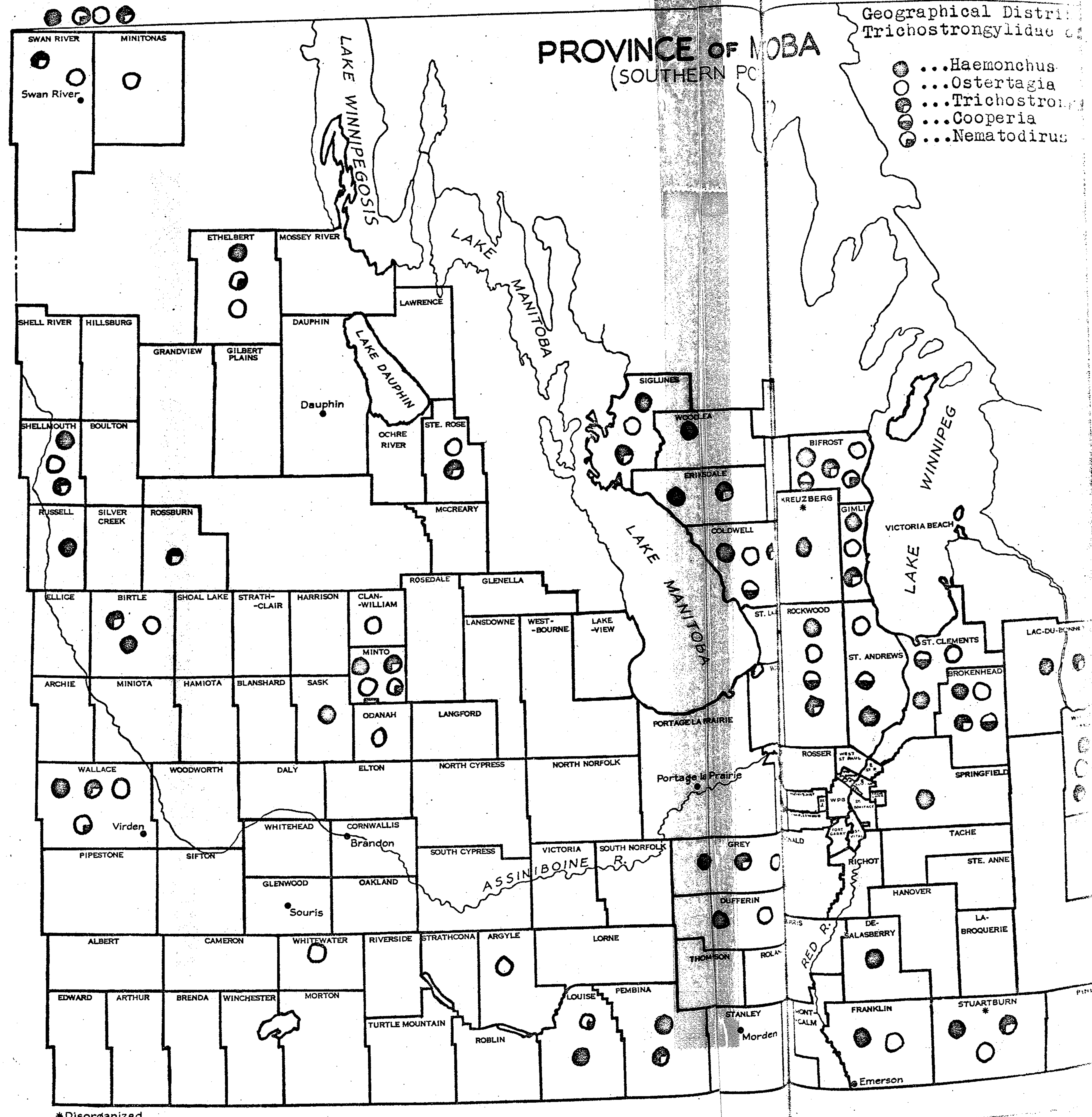
Rossburn: Trichostrongylus, Moniezia.

Birtle: Trichostrongylus, Bunostomum, Ostertagia, Haemonchus, Chabertia.

ELKHORN:

Sifton: 000000

Wallace: Ostertagia, Trichostrongylus, Moniezia, Nematodirus, Haemonchus, Dictyocaulus.



Geographical Distri
Trichostrongylidae
...Haemonchus
...Ostertagia
...Trichostro
...Cooperia
...Nematodirus
PROVINCE OF
(SOUTHERN
LAKE WINNIPEGOSIS
LAKE MANITOBA
LAKE DAUPHIN
LAKE WINNIPEG
ASSINIBOINE R.
RED R.
SWAN RIVER
MINITONAS
Swan River
ETHELBERT
MOSSEY RIVER
LAWRENCE
DAUPHIN
Dauphin
SHELL RIVER
HILLSBURG
GRANDVIEW
GILBERT PLAINS
OCHRE RIVER
STE. ROSE
SHELLMOUTH
BOULTON
RUSSELL
SILVER CREEK
ROSSBURN
McCREARY
ROSEDALE
GLENELLA
ELLICE
BIRTLE
SHOAL LAKE
STRATH-CLAIR
HARRISON
CLAN-WILLIAM
MINTO
LANSDOWNE
WEST-BOURNE
LAKE VIEW
ARCHIE
MINIOTA
HAMIOTA
BLANSHARD
SASK
ODANAH
LANGFORD
PORTAGE LA PRAIRIE
Portage la Prairie
WALLACE
WOODWORTH
DALY
ELTON
NORTH CYPRESS
NORTH NORFOLK
Virden
WHITEHEAD
CORNWALLIS
Brandon
PIPESTONE
SIFTON
SOUTH CYPRESS
VICTORIA
SOUTH NORFOLK
GLENWOOD
OAKLAND
Souris
ALBERT
CAMERON
WHITEWATER
RIVERSIDE
STRATHCONA
ARGYLE
LORNE
EDWARD
ARTHUR
BRENDA
WINCHESTER
MORTON
TURTLE MOUNTAIN
ROBLIN
LOUISE
PEMBINA
SIGLUNES
WOODLEA
ERIKSDALE
COLDWELL
BIFROST
KREUZBERG
GIMLI
VICTORIA BEACH
ROCKWOOD
ST. ANDREWS
ST. CLEMENTS
BROKENHEAD
LAC-DU-BONNET
ROSSER
SPRINGFIELD
TACHE
STE. ANNE
RICHOT
HANOVER
GREY
DUFFERIN
THOMPSON
DE-SALASBERRY
LA-BROQUERIE
STANLEY
Morden
FRANKLIN
STUARTBURN
Emerson
*Disorganized

For several years prior to this survey, the rainfall was appreciably higher than average in this area. The wet weather in the fall preceding the survey resulted in a low feed supply for many sheep raisers. Coupled with this, there was a late spring in 1945 and owners could not turn their flocks out to forage as early as in other years. All these factors resulted in a poor nutritional state of most of the animals, which made them particularly susceptible to parasitism(23).

It will be noted that the true prairie region in the south-western part of the province is practically free of parasites. The native vegetation here consists of mixed short and tall grasses. The soil is well drained and is high in organic matter at the surface, but not lower down in the profile(18).

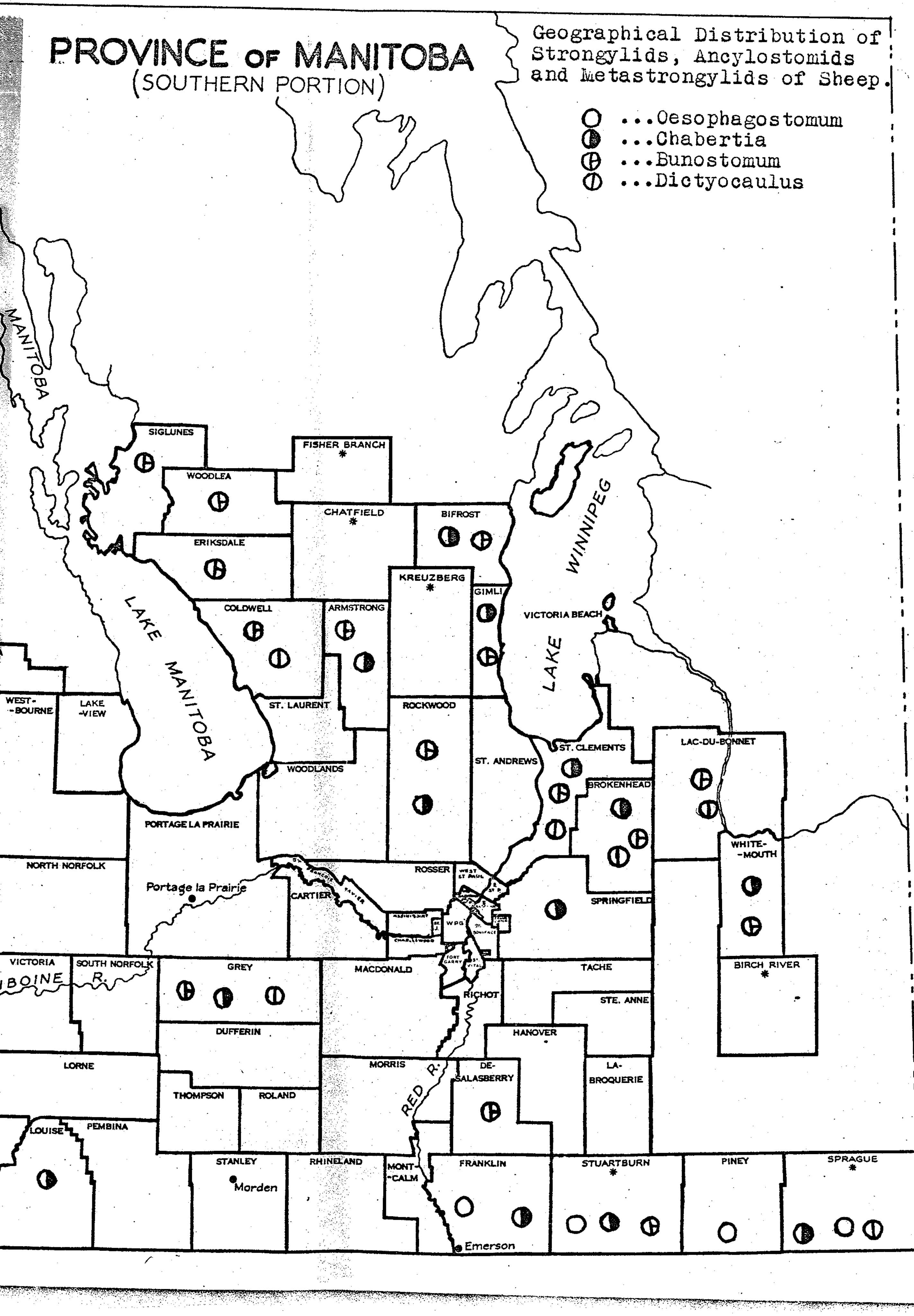
Note: The position of a symbol inside a Municipality on the map has no relation to the exact location of a parasitic species within the Municipality, but merely indicates its presence.

Map II shows the geographical distribution of the Strongylids, Ancylostomids, and Metastrongylids. Of the two genera of Strongylids, Chabertia is as widely distributed as the Trichostrongyles, while Oesophagostomum is confined to one area. It will be noted that the latter species occur only east of the Red River along the United States border. The soil here is either high lime or swampy(18).

Bunostomum is the only Ancylostomid type of worm found here in sheep and its distribution is general.

Dicyocaulus, the large lung worm, is much more general in distribution than was believed hitherto. It is found in low, marshy areas only, or in other areas where sheep have access to sloughs.

Note: The position of a symbol inside a Municipality on the map has no relation to the exact location of a parasitic species within the Municipality, but merely indicates its presence.


PROVINCE OF MANITOBA
(SOUTHERN PORTION)
Geographical Distribution of Strongylids, Ancylostomids and Metastrongylids of Sheep.
...Oesophagostomum
...Chabertia
...Bunostomum
...Dictyocaulus
MANITOBA
SIGLUNES
FISHER BRANCH
WOODLEA
CHATFIELD
BIFROST
ERIKSDALE
KREUZBERG
GIMLI
WINNIPEG
LAKE MANITOBA
COLDWELL
ARMSTRONG
VICTORIA BEACH
LAKE
WEST-
-BOURNE
LAKE
-VIEW
ST. LAURENT
ROCKWOOD
ST. ANDREWS
ST. CLEMENTS
LAC-DU-BONNET
WOODLANDS
BROKENHEAD
PORTAGE LA PRAIRIE
WHITE-
-MOUTH
NORTH NORFOLK
ROSSER
Portage la Prairie
CARTIER
SPRINGFIELD
VICTORIA
SOUTH NORFOLK
GREY
MACDONALD
TACHE
BIRCH RIVER
RICHOT
STE. ANNE
DUFFERIN
HANOVER
LORNE
MORRIS
DE-
SALASBERRY
LA-
BROQUERIE
THOMPSON
ROLAND
RED R.
LOUISE
PEMBINA
STANLEY
RHINELAND
MONT-
-CALM
FRANKLIN
STUARTBURN
PINEY
SPRAGUE
Morden
Emerson

DISTRIBUTION OF PARASITES IN THE HOST

The majority of parasites exhibit location specificity within the host. Figure II shows the sites at which the different species were taken at post mortem during the present survey. A description of the various parasites, as they appeared to the writer, is also given.

The measurements given, for the most part are those of Yorke and Maplestone. The few measurements made by the writer were all within the limits of those given by Yorke and Maplestone, with the exception of Mecistocirrus. This species exceeded the upper limits of Yorke and Maplestone's measurements(68), but agreed with the figure listed by Monnig(41). The size of the cysts of _T. hydatigena_ is also listed from Monnig.

The specificity of most of these parasites for particular cites is of great diagnostic value in the field, although frequently species can be found in locations other than the normal.

FIGURE II

DISTRIBUTION OF PARASITES IN THE HOST AT POST-MORTEM

Site of Infection	Species	Gross Description
Lungs	Dictyocaulus filaria	Occur as white, thread-like masses in the air passages. Males 1.5 to 3 inches long and females up to 4 inches long.
Fourth Stomach (Abomasum)	Haemonchus contortus	Slender, reddish worms. Females have a twisted or barber-pole appearance on close examination. Males 10-20mm. long; females 18-30mm. long. Females have a vaginal flap.
Fourth Stomach	Ostertagia circumcincta	Tiny, brownish, hair-like worms on the mucosa of the abomasum. Males 6.5-7.5mm; females 8.3-9.2mm. long.
Fourth Stomach	Mecistocirrus digitatus	Specimens look like Haemonchus, but females lack vaginal flap. Somewhat larger than Haemonchus, Females up to 35 mm. long.
Small Intestine (anterior end)	Trichostrongylus colubriformis	Tiny, hair-like worms on the surface of the mucosa, forming a hairy mat if very numerous. Males 5-6mm; females 6-8mm. long.
Small Intestine (anterior end)	Cooperia curticei	Tiny, hair-like worms on the surface of the mucosa. Easily mistaken for immature forms of other species. Males 4.6-5.4mm long; females 5.8-6.2mm long.
Small Intestine (anterior end)	Nematodirus spp.	Very slender, thread-necked worms. The anterior third of the body is much more slender than the posterior two thirds. Males 4.6-5.4mm; females 6-8mm long.

2

Site of Infection	Species	Gross Description
Small Intestine (posterior end)	*Bunostomum trigoncephalum*	Worms about one inch long, bent dorsally at anterior end. Usually attached to the intestinal wall anteriorly, the rest of the worm lying close to the mucosa. previous points of attachment seen as small hemorrhagic areas on gut. Males 12-17mm long; females 19-26mm long.
Small Intestine (posterior end)	*Moniezia spp.*	Tapeworm. Long, white ribbon of segments becoming progressively broader posteriorly. At post-mortem can sometimes be seen as white objects through intestinal wall.
Caecum	*Trichuris ovis*	Anterior hair-like and often attached to the mucosa. Posterior much stouter. Posterior of male coiled into spiral. Posterior of female curved slightly, 35-70mm long. Only posterior part visible in situ.
Large Intestine	*Chabertia ovina*	White, shiny, relatively stout-bodied worms attached to the thick mucosa of the large intestine. Anterior bent slightly ventrally. Males 13-14mm long; females 17-20mm long.
In Body Cavity and on Organs	*Cysticercus tenuicollis*	Bladder-like structure up to one inch in diameter, filled with a clear fluid. Found attached to the liver, caecum, paunch and other parts of the abdominal cavity.

AGE RESISTANCE

Younger animals are usually more severely parasitized than older ones. Investigators have been aware of a factor called "age resistance" for some time, and some have referred to this mechanism when discussing the factors influencing parasitism(26,62).

Effects of first exposures are the most severe, hence lambs are more adversely affected than older animals. After animals have recovered from one parasitic infection, they will rarely pick up another heavy worm burden, provided they are kept in a fair nutritional state.

This mechanism is admirably demonstrated with the data from the faecal examination of 135 sheep at the University of Manitoba during the summer of 1944. Of the 135 sheep examined, 77 were over one year old, while the other 58 were spring lambs. All the animals were exposed to the same environmental conditions during the summer. Practically all the young animals became parasitized on pasture, whereas a good proportion of the older sheep remained free of parasitic infection. As the only difference between these sheep was their age, the data has been set out in Table IV, and treated statistically to determine existing significance.

TABLE IV

	Young Sheep	Old Sheep	Total
Parasitized	57	55	112
Non-parasitized	1	22	23
Total	58	77	135

$$\text{Chi-square} = \frac{(57 \times 22) \quad (55 \times 1) \times 135}{58 \times 77 \times 112 \times 23} = 16.87$$

The above data, when analysed by the Chi-square test as outlined by Goulden, yield a value of 16.87(26). There is only a single degree of freedom for the above analysis. Looking up the table of Chi-square under one degree of freedom, it is found that 6.64, the largest number listed, has a P value of 0.01. The value obtained here is still larger, and therefore has a still smaller P value. This means that a value as large or larger than 16.87 would be obtained by chance, less than once in a hundred tries. The greater ability of older sheep to resist infection by parasites has been proven to be significant.

SIZE OF FLOCK AND INCIDENCE OF PARASITISM

The close grazing habits and gregariousness of sheep are aids to the rapid spread and increase of parasitic diseases. It is reasonable to assume, then, that larger flocks will have a higher incidence of parasitism than smaller ones.

In the field, small flocks of 12 to 15 sheep were never found to harbour many worms. The larger flocks, particularly if their grazing area was restricted, were always parasitized to a larger extent, unless anthelmintic treatment had been resorted to.

It was the writer's intention to measure the degree of correlation that exists between the size of flocks and the incidence of parasitism. The present data were found to be influenced by too many uncontrollable variables for the calculation of such a correlation. The differences in flock management, climate and anthelmintic treatment, for example, from farm to farm and district to district can not be segregated into measurable units.

A correlation coefficient calculated from this type of survey data would be meaningless, because the experiment was not designed to be analysed in this way. To measure this correlation, if such exists, will require the designing of an experiment in such a way as to avoid the influence of uncontrollable variables in the analysis.

TABLE V

THE SIZE OF FARM FLOCKS AND THE INCIDENCE OF PARASITISM

District	Average Size of farm	Average Size of flock	Percentage of Sheep Parasitized	Percentage of Farms Parasitized
Eriksdale	506 acres	72	60.0%	100.0%
Seven Sisters	255 acres	82	44.1	100.0
Selkirk	1337 acres	102	58.5	100.0
Teulon	422 acres	56	36.2	93.8
Vita	232 acres	41	23.0	80.0
Minnedosa	415 acres	56	22.0	60.0
Russell	880 acres	90	46.0	100.0
Carman	310 acres	375	25.0	100.0
St. Pierre	267 acres	74	10.0	60.0
Pilot Mound	368 acres	47	14.0	40.0
Boissevain	720 acres	30	2.5	25.0
Dauphin	327 acres	96	6.7	36.4
Swan River	251 acres	30	14.7	75.0
Shoal Lake	920 acres	272	32.5	100.0
Elkhorn	1440 acres	128	47.8	50.0

Table V indicates that flock size bears a relationship to incidence of parasitism. It will be noted that in practically every district where the average size of the flocks is over 70 sheep, the incidence of parasitism is 100 percent of the flocks.

DESCRIPTION, LIFE-CYCLE AND PATHOGENICITY OF LOCAL SPECIES

Information regarding the identity, life-cycle and pathology of the local parasitic forms has been accumulated for all the parasites uncovered in this survey. As there are 6 different genera of Trichostrongyles present in Manitoba sheep, an identification key has been constructed for the local forms of Trichostrongylid worms.

The other nematodes are so vastly different from each other that such a key is not necessary for their differentiation.

MANITOBA GENERA

KEY TO LOCAL SPECIES OF TRICHOSTRONGYLIDAE IN SHEEP

Parasites of the alimentary canal with a more or less filiform body. Mouth simple and directed straight forward; buccal capsule absent or rudimentary. Bursa copulatrix of males with well developed lateral lobes and dorsal lobe either not differentiated or very small. Genitalia of female are double.

1. Spicules short with crests and protuberances............2

   Spicules long, without crests and protuberances.........6

2. Cervical papillae present...............................3

   Cervical papillae absent................................5

3. Dorsal lobe of male bursa asymmetrical..*Haemonchus*

   Dorsal lobe of male bursa symmetrical...................4

4. Accessory bursal membrane present......*Ostertagia*

   Accessory bursal membrane absent........................5

5. Head dilated and transversely striated, giving it a bulbous appearance......................*Cooperia*

   Head small, not dilated and not bulbous in appearance............................*Trichostrongylus*

6. Cephalic cuticle dilated, cervical papillae absent ....*Nematodirus*

   Cephalic cuticle not dilated, cervical papillae present ....*Mecistocirrus*

Ostertagia circumcincta(Stadelmann,1894)...the brown or medium stomach worm.

These worms are tiny, brownish, hair-like forms that are often covered by a layer of mucous in the stomach. Two small cervical papillae are present (Figure 3). The male spicules are equal, straight and parallel, and are cleft distally (Figure 4). These worms measure less than 10 mm. in length.

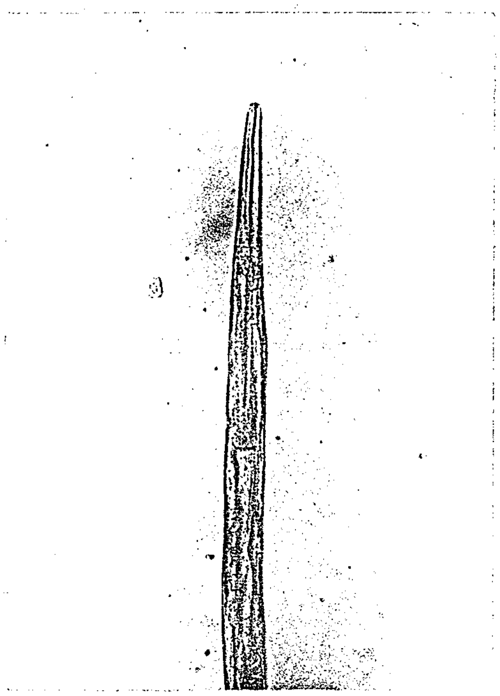


Figure 3 O.circumcincta
Anterior end.

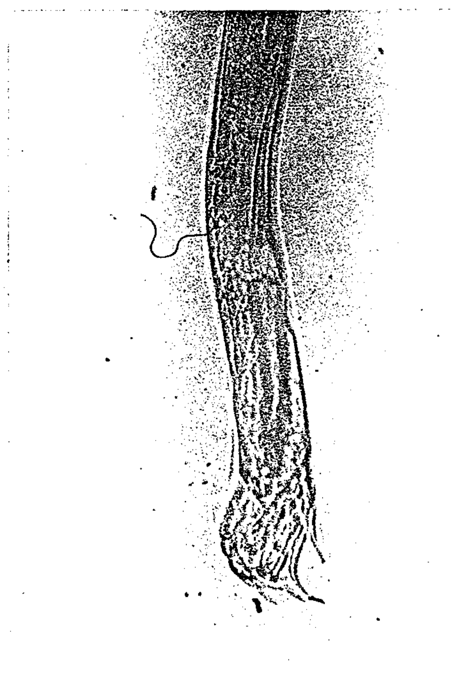


Figure 4 O.circumcincta
Male bursa and spicules

Ostertagia circumcincta

Life cycle(64): Infection takes place by ingestion of larvae of the third or infective stage. The eggs reach the four-celled stage in the adult female, and the morula stage by the time they pass out of the host with the faeces. The newly hatched larvae soon develop a sheath. On the third or fourth day the larvae develop a sheath. On the third or fourth day the larvae develop into the larger second stage and on the fifth or sixth day the third or infective stage is reached. These larvae are ensheathed and do not develop any more till they are ingested by the host. By the fourth day after ingestion the larvae have reached the abomasum and are sexually differentiated. They are found in the mucosa in areas that are slightly raised, and show tiny hemorrhagic spots. The mucosa of the abomasum becomes inflamed if many larvae are present. Small nodules are evident on the mucosa. Larvae and some adults leave the nodules and take up their position on the surface of the mucos, usually covered by a layer of mucous. Dikmans and Andrews report gravid females appear about the fifteenth day after infection(12).

Pathogenicity(63): Ostertagia cause loss of weight in old sheep and retard growth in lambs. There is a decrease in the percentage of hemoglobin, a decrease in the percentage of lymphocytes, and a pronounced eosinophilia. Sheep become "pot-bellied" and the wool becomes very rough and dry. The animals become constipated intermittently, and exhibit shallow and rapid breathing during these periods.

Haemonchus contortus(Rudolphi,1803)...the common stomach worm.

These worms measure from 10 to 20 mm. in length and appear reddish in color when they are alive in the stomach. The female has the uteri wound spirally around the intestine, which gives the worm a peculiar barber-pole effect, particularly when the intestine is filled with ingested blood. The female has a prominent vaginal flap(Figure 6). Cervical papillae are present in both males and females(Figure 5). The male spicules are equal and the distal points are close together (Figure 7). The dorsal lobe of the bursa is asymmetrical, and is supported by a Y-shaped dorsal ray(Figure 7).

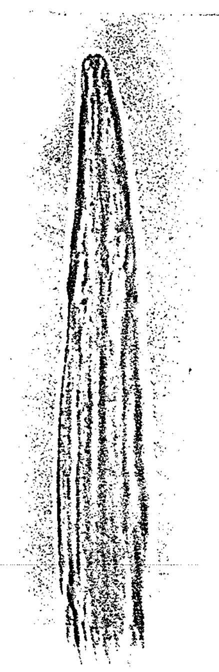


Figure 5 H.contortus.
Anterior end.

Figure 6 H.contortus.
Female Vaginal Flap

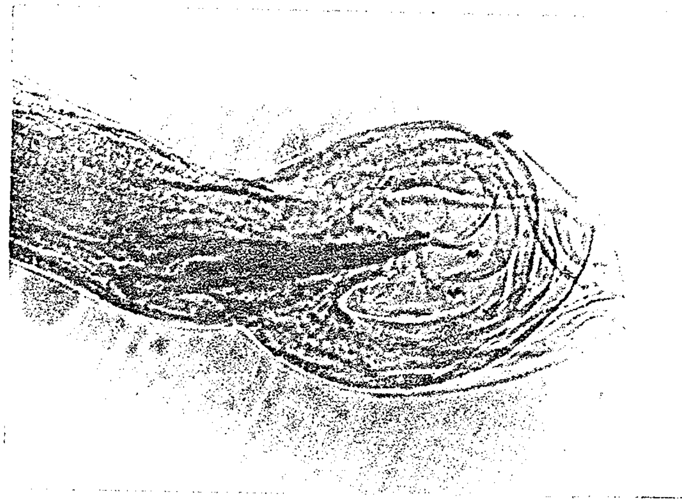


Figure 7 H.contortus. Male bursa and spicules.

Life Cycle(41): The life cycle is like that of Ostertagia, but the adult worms are not covered by a layer of mucous.

Pathogenicity: Sheep infected with Haemonchus appear thin, rough in coat, "pot-bellied", diarrhoeic, and sometimes "bottle-jawed". "Bottle-jawed" is a term used to denote a localized edema that occurs below the lower jaw. The skin and membranes of the eye appear very pale. On post mortem the stomach contents are brownish in color from hemorrhage caused by the parasites. The anemia of haemonchosis is due to gastric hemorrhage alone, as the icteric index of the blood remains normal(6). Sheep can lose up to 2.5 times their original volume of blood in a period of 15 days from a heavy infection. This accounts for some of the fatal cases that are encountered before the eggs can be found in the faeces.

<u>Trichostrongylus colubriformis</u>(Giles,1892)...the black-scour worms.

These are very tiny hairworms that are very much attenuated anteriorly. There are no cervical papillae. The male spicules are equal, short, and very twisted, with angular projections at the distal ends which give them a barbed and twisted appearance(Figure 8).

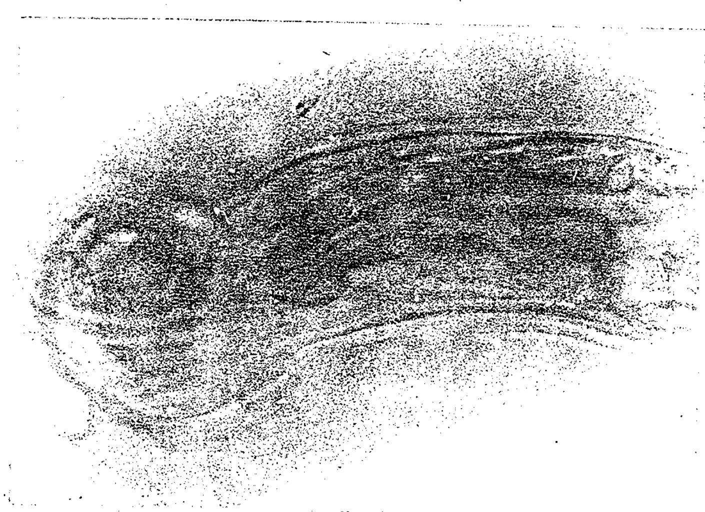


Figure 8 *T.colubriformis*.
Male spicules.

Trichostrongylus colubriformis

Life Cycle: The life cycle is typically Trichostrongylid like that of Ostertagia, but the eggs have reached the 16 to 32 celled stage when they are laid and the infective larvae enter the mucosa of the small intestine instead of the abomasum. Eggs are not passed in the faeces till three weeks after infection(41).

Pathogenicity(4): Trichostrongylus infections bring about profuse, dark, watery diarrhoea. This diarrhoea is so severe that death of the host sometimes occurs before any eggs can be found in the faeces. These conditions are due to partial starvation and also to the dehydration of the tissues. In animals dying after a brief infection there is no anemia but in cases of prolonged infestations animals become very emaciated. Death from Trichostrongylus is due to a disturbance of the circulation and also degenerative changes in the liver and kidneys. Even in mild infections of Trichostrongylus Andrews et al found that feed was utilized less efficiently by lambs due to an increased energy metabolism which in turn was "due to local nerve irritation and inflammation of the intestine brought about by the presence of the worms(7)".

Cooperia curticei(Railliet,1893)...the cooperia worms.

The heads of these worms are relatively thick but the lips are not well marked. The anterior ends of the worms are somewhat dilated and transversely striated (Figure 9). Cervical papillae are absent. The dorsal ray of the bursa has two branches which form a horseshoe-shaped structure. Each branch has a lateral twig at the mid-point. The spicules are short and stout, and have simple points(Figure 10).

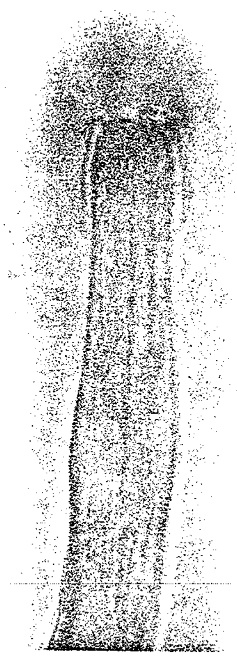


Figure 9 C.curticei.
Anterior end.

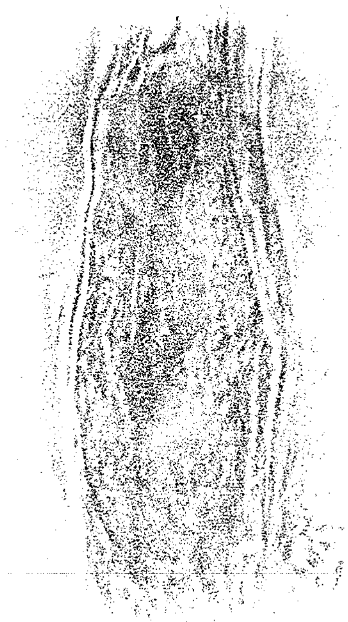


Figure 10 C.curticei.
Male spicules.

Cooperia curticei

Life cycle: The eggs of Cooperia hatch about 20 hours after being passed in the faeces, with larvae reaching the infective stage about 90 hours after hatching. Infective larvae soon lose their sheaths in the host, and make their way into the crypts of the anterior portion of the small intestine. They never burrow into the mucosa, and leave the crypts for the lumen of the intestine after the third ecdysis. By the fourteenth day the worms are mature, and eggs can be found in the faeces on the fifteenth day after infection. Resistant animals produce nodules around the larvae, even though the mucosa is never penetrated(5).

Pathogenicity: Although this worm is relatively non-pathogenic, Grahame has recorded instances where this species caused fatal effects in goats(27). He reports that diarrhoea is the first sign of abnormality. The infected animal's appetite becomes erratic with a consequent loss of condition, and the ones that die show signs of abdominal pain. Andrews has shown that even slight infestations of Cooperia in lambs that show no signs of parasitism, still decreases the ability to convert feed into gain(3).

<u>Nematodirus</u> <u>spp</u>. ...the thread-necked strongyles.

These worms are filiform and very attenuated anteriorly. The cephalic cuticle is dilated and expanded into a balloon-like structure(Figure 11). The female has a conical tail, which bears a small, pointed, process. The eggs in utero are large and have a clear space between the shell and the embryonic cells. The male spicules are long and filiform, and are united by a membrane. Two species of this genus occur in Manitoba sheep.

<u>N. filicollis</u>(Rud.,1802)...The male spicules terminate in a sharp, pointed, membrane(21). Mature females contain eggs that are oval and fairly smooth in outline(33).

<u>N. spathiger</u>(Railliet,1896)...The male spicules terminate in a blunt, spatulate, membrane(21). Mature females contain eggs that are larger, more oblong and more tapering than these of filicollis. The shells are more or less thickened at the ends.

Figure 11.<u>Nematodirus</u> <u>spp</u>.
Dilated Cuticle

Nematodirus spp.

Life Cycle(9): The life cycle of Nematodirus differs from that of the other Trichostrongylids dealt with in that the larvae undergo two ecdyses inside the egg shell. Upon hatching they still have the outer skin of the second stage. The larvae loses this sheath upon entering the sheep. The eggs of this species as well as the larvae are capable of infecting sheep upon being ingested, although infection by larvae is more common. The adult worms occur free in the lumen of the intestine. Eggs appear in the faeces on the twentieth day after infection(1).

Pathogenicity: There is little information available in the literature regarding the pathogenicity of Nematodirus, and the existing literature is not in agreement. Kauzal regards Nematodirus as a species of low pathogenic importance, but admits that his artificially infected animals were not heavily infected(35). On the other hand, Ryksen has reported marked pathogenic effects of Nematodirus, with the infected animals showing signs of "marked emaciation and weakness without diarrhoea"(49). Hepatization of the lungs was reported by the same author. In the present survey at least one instance was encountered where a one year old wether was in a moribund condition, and post-mortem showed an almost pure infestation of Nematodirus species.

Although the specific pathological changes produced by this species are not known, it is the author's opinion that heavy infestations of Nematodirus alone are very detrimental to the well-being of the host.

Mecistocirrus digitatus(Linstow,1906)...

Only females of this species were found during the survey and were originally mistaken for Haemonchus, because the two species occurred together in the abomasum, and both showed the characteristic barber-pole effect when observed with the naked eye. Upon microscopical examination the two were differentiated on the basis of the female genital characteristics. Mecistocirrus lacks a vaginal flap, and the vaginal pore is situated near the anal opening(Figure 12). No males of Mecistocirrus were found.

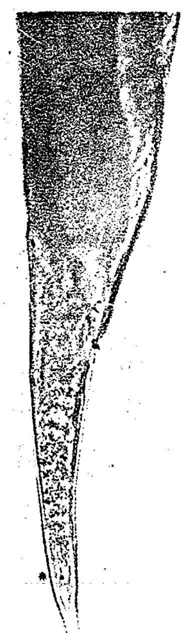


Figure 12 M.digitatus.
Female posterior end.

Relatively few worms of this species were encountered during the survey, and the relatively small males may have been overlooked in the much heavier Haemonchus infections. The females are slightly larger than those of Haemonchus, and have the body attenuated anteriorly. The head is small with the head slightly sub-terminal. The opening is slightly dorsal and shows the presence of a small buccal tooth. The cuticle is somewhat striated and cervical papillae are present. The female has the vulva and the anus close together(Figure 11). The post-anal portion of the female is conical.

Life Cycle: This parasite was at one time considered as a species of Nematodirus(24), but resembles Haemonchus in appearance. Its life cycle may resemble that of either of these species. In any case, the parasite is a Trichostrongylid, and its life cycle must therefore be direct.

Pathogenicity: Monnig lists the pathogenicity of this species as "very similar to Haemonchus"(41). In the present survey this species was found in small numbers only, and always in mixed infections, so that no observation on its effect on the host could be made.

STRONGYLIDAE

Oesophagostomum columbianum (Curtice,1890): the nodular worm.

The actual parasites were not taken. Post-mortem field examination of sheep with nodulated intestines, and nodulated viscera from packing plants failed to yield a single adult nodular worm. This is probably due to the resistance of adult sheep to nodular worms. Freeborn and Stewart are of the opinion that fourth stage larvae and adult worms are sometimes voided in the faeces as soon as they venture out of the cysts(24). The worms are swept out of the lumen of the intestine in diarrhoeal attacks leaving only the caseated nodules behind. In lambs the worms persist much longer than in adult sheep, but due to lack of time, and the limited distribution of the parasite in Manitoba, it was not possible for the investigator to examine lambs for nodular worms. The evidence that nodular worms occur in south-eastern Manitoba is based on the presence of the typical nodules on the guts of sheep in this area. The eggs of this species were also found in the faeces of sheep in this area. The eggs are very similar to those of Haemonchus, but can be distinguished on the basis of their normal deep color, small number of cells (4 to 16), and poorly defined cell membranes(33). The fact that the presence of Oesophagostomum has also been reported from areas in the United States directly south of Manitoba(42) is further evidence that the nodules found here are those of Oesophagostomum.

Life cycle: The life cycle of *O. columbianum* resembles that of Trichostrongylid worms up to the infective stage. These infective larvae exsheath and burrow into the lining of the intestine to the muscular layer. The host reacts to the presence of the worms by forming cysts around the parasites. A number of these cysts together form nodules that resemble peas in size and shape. The larvae grow inside the cysts and finally re-enter the lumen of the intestine. The nodules then become filled with a yellowish-green, cheezy material. Larvae usually remain in the cysts for about 5 days(22).

The larval worms mature in the lumen of the intestine and may persist there for long periods of time in lambs, but in adult sheep the adults and fourth stage larvae "are swept out of the body in diarrhoeal attacks" (24) after emerging from the nodules. These nodules have been observed in a number of cases, but not a single adult worm could be taken during the present survey, as all the post-mortems in the nodular area of the province happened to be conducted on adult sheep.

Pathogenicity: The nodules weaken the intestinal wall so that rupture and peritonitis are apt to follow(19). The lesions made by the worms predisposes the animal to secondary infections. Infected animals become anemic and emaciated, and may also show paralysis of the legs(24).

Chabertia ovina(Fab.,1788)...the large-mouthed bowel worm.

These are relatively stout, shiny, white worms that measure from 13 to 20 mm. in length. The mouth is directed antero-ventrally, and possesses two very small leaf crowns. The buccal capsule is sub-globular and without teeth in its depth(Figure 13). The male spicules are equal, long and slender. The male bursa is symmetrical and not very large(Figure 15). The female has the anus and the vagina close together and near the posterior end (Figure 14).

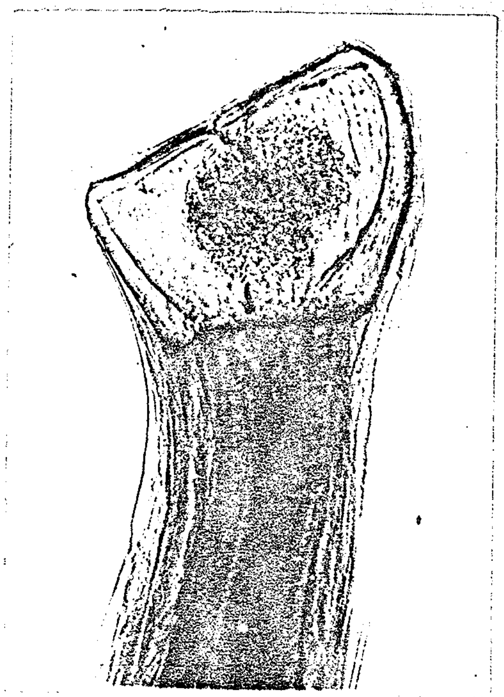


Figure 13 C.ovina
Buccal capsule

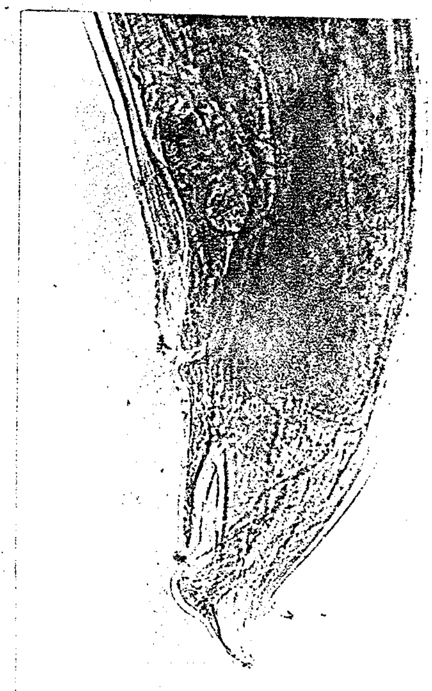


Figure 14 C.ovina.
Female posterior end.

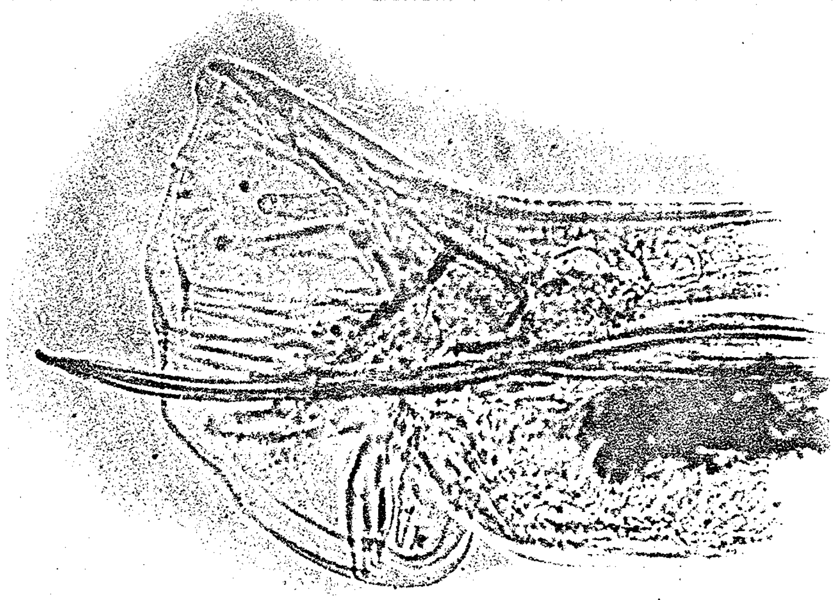


Figure 15 _C. ovina_. Male bursa and spicules.

Life cycle: A search of the literature fails to reveal any detailed study of the life cycle of this very common species. It is probably reasonable to assume that the cycle resembles that of the Trichostrongylid worms, but the details remain to be worked out. It is known that the eggs found in the faeces of infected animals are in the morula stage(33). Fourth stage larvae have been taken from the large intestine of sheep by Griffiths, which is also the cite of the adult worms(29).

Pathogenicity: Kauzal has shown that immature C. ovina ingest considerable quantities of blood(34). Threlkeld's experiments, using defibrinated sheep's blood, indicate a possible hemolytic factor in Chabertia as the harmful element in infections of this parasite(65). Sheep with heavy infections of C. ovina show a loss of weight, profuse, bloody slimy diarrhoea and a drop in haemoglobin and erythrocytes.

<u>Bunostomum</u> <u>trigoncephalum</u>(Rud.,1808)...a sheep hookworm.

The adult worms measure from 12 to 26 mm. in length. Their mouths are directed antero-dorsally(68). The buccal capsule is sub-globular and has three small lancets in its depth. The lateral view in Figure 16 shows these lancets as a larger, pointed, dorsal one and two smaller ventral ones. Figure 17 shows the two semi-lunar cutting plates at the oral margin of the buccal capsule as they are seen in the dorsal view. The male bursa consists of two large symmetrical lobes and a smaller, asymmetrical dorsal lobe. The male spicules are equal, pointed and twisted about each other(Figure 18). There is no gubernaculum. The ventral and lateral rays all arise from a large common trunk(Figure 18). The dorsal ray is bifurcate and each branch is bidigitate (Figure 18). In the female the vulva is in front of the middle of the body and is quite distinct(Figure 19). The posterior extremity of the female is rather pointed(Figure 20).

Figure 16 B.trigoncephalum
Buccal capsule, lateral view.

Figure 17 B.trigoncephalum
Buccal capsule, dorsal view.

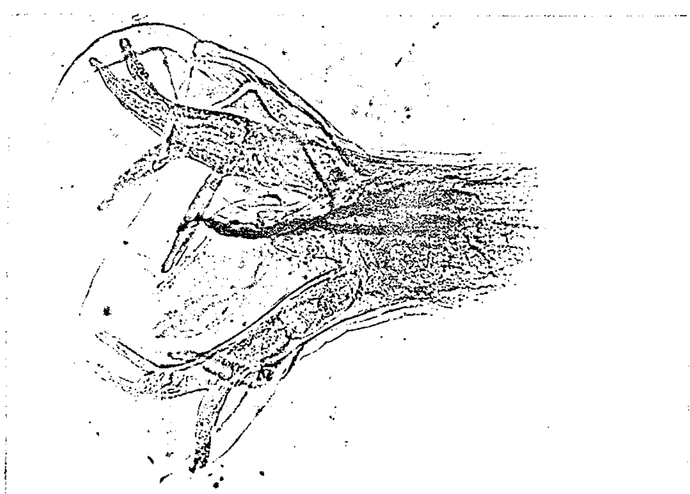


Figure 18 B.trigoncephalum.Male bursa and spicules.

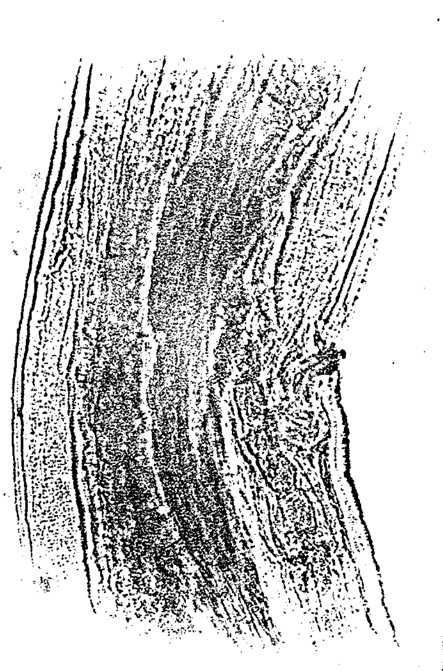


Figure 19 B.trigocephalum
Vaginal pore of female.

Figure 20 B.trigocephalum
Female posterior end.

Life Cycle: The life cycle of this parasite is not of the typical nematode type, in that the infective larvae can gain entrance to the host by active penetration of the skin as well as orally. Freeborn and Stewart in 1937 claimed that Bunostomum could not penetrate the skin(24). In 1944, Lucker, however was able to infect a lamb with this species by percutaneous injections of larvae, when oral administration had failed to infect the animal(37). Ortlepp has definitely proved that the infective larvae do penetrate the skin and then make their way to the lungs via the blood stream(43). This requires about six days.

The larvae spend about 5 days in the lungs, feeding and growing. By this time they have reached the fourth stage and are provided with a provisional buccal capsule. Larvae now migrate to the small intestine, where they become sexually differentiated. They become attached to the intestinal villi and feed on blood. The egg-laying stage is not reached till 9 or 10 weeks after infection.

Pathogenicity: Bunostomum is a blood sucker and changes its point of attachment frequently, leaving small points of hemorrhage which bleed for some time. By active blood sucking and secondary hemorrhage these worms cause severe anemia in sheep. Sometimes animals die 7 weeks after infection, before eggs of the parasite can be found in the faeces of the infected sheep(37). Blood can be found in the faeces of infected animals. Lucker found that both hemoglobin and erythrocytes were reduced in the blood of infected animals(37).

Whether larvae which enter the host per orum pass directly into the intestine, or migrate through the lungs first, has not yet been proven, but it is likely that all Bunostomum larvae migrate through the lungs. This opinion comes from the observation that the transitional stage between third and fourth stage larvae has never been encountered in the intestine, but has been found in the lungs(43).

Where Bunostomum larvae pass through the lungs, Ortlepp observed punctate hemorrhagic markings on the outer surface of these organs. Some lungs showed extensive internal bleeding on sectioning(43). During the present survey these points of hemorrhage have sometimes been noted on the lungs of animals at post-mortem, but their presence was not connected with the hookworm infection at the time.

From the above observations it can be seen that Bunostomum is a very pathogenic parasite of sheep, and its wide distribution in Manitoba adds to its importance here.

METASTRONGYLIDAE

Dictyocaulus filaria(Rudolphi,1809)...The thread lung worm of sheep.

These are long, thread-like, whitish worms. The anterior end terminates bluntly in a shallow mouth(Figure 21). The spicules are short, blunt, stout and equal (Figure 22). The vulva of the female is near the middle of the body. In the uteri of cleared females, eggs containing coiled larvae are often visible.

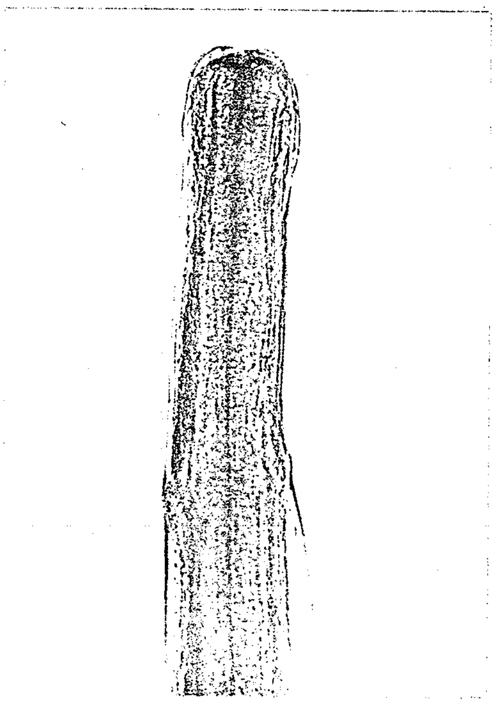


Figure 21 D.filaria.
Anterior end.

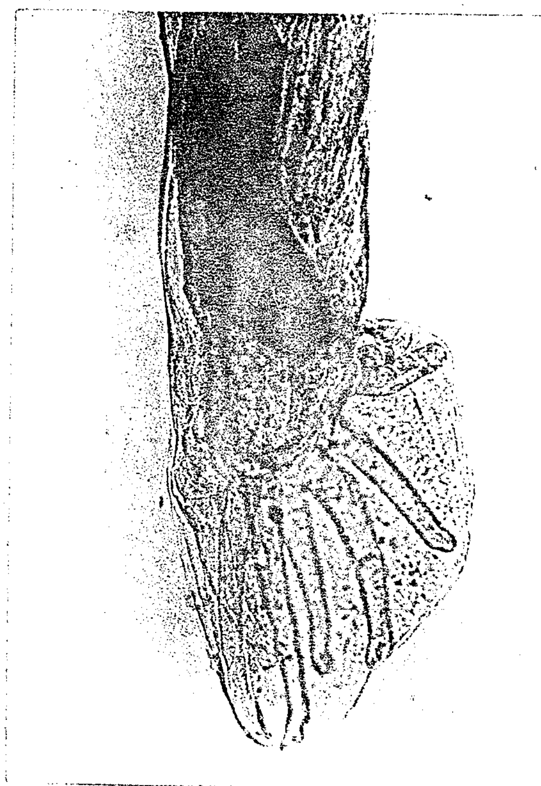


Figure 22 D.filaria.
Male bursa and spicules.

<u>Life Cycle</u>: The eggs of this species contain a coiled larvae at the time of deposition. These eggs hatch readily soon after they are laid. This can easily be observed by placing some freshly deposited eggs on a slide or petri dish.

The eggs or young larvae are coughed up from the lungs and swallowed. The larvae then pass out in the faeces, and after a period of development in moist locations, become infective. Infective larvae can be ingested with either food or water(24). The larvae then penetrate the walls of the intestine to the lymph nodes, develop some more, and pass to the lungs by means of the circulatory system. Here they bore into the air passages and develop into adult worms.

According to Mitten larvae sometimes become lodged in other organs such as the liver, or in the case of pregnant ewes, in the unborn lamb(40). This point is of particular importance here, for during the survey the writer noticed that wherever lungworms were found in abundance, the flock owners complained of a high mortality loss in the lamb crop. In one specific case where over 200 adult <u>D. filaria</u> were taken from one animal, the owner of 80 ewes had only 2 lambs surviving from the spring crop. The infestation here was severe and many sheep had died during the winter, presumably from lung worm infections. It is very likely that many of the new born lambs died because of complications in the pulmonary system due to Dictyocaulus larvae lodged in the foetal lungs.

Pathogenicity: Sheep infected with D. filaria exhibit shallow, rapid breathing and tire easily. They lose their appetites and become very thin. The wool takes on a dry, dull appearance. Infected animals will be seen to lower their heads and cough for long periods at a time. The cough is a particularly husky variety, as though the animal was trying to remove something from its lungs. Some animals strain to such an extent while coughing, that the rectum becomes everted.

TRICHURIDAE

Trichuris ovis(Abildgaard,1795)...the sheep whipworm.

The anterior portion of the worm is long and attenuated. This filiform portion is usually found attached to the mucosa of the caecum, and the short, thicker, posterior portion is seen free in the lumen. The male posterior is rolled into a tight curl, while the female posterior is only slightly bent. The male has a single spicule, which is usually hard to see because the posterior portion of the body is coiled. The eggs of this species are lemon-shaped and have a protruding plug at each end. The female vaginal pore is located on the swollen posterior portion near the junction of the filiform anterior portion.

Life cycle(41): The larvae develops to the infective stage inside the egg and becomes infective after about three weeks. Infection is brought about by ingestion of the eggs, which then hatch in the intestine. The larvae migrate to the caecum and mature.

Pathogenicity: Some authors(41, 24) claim that whipworms produce a severe inflammation in the intestine and caecum, but during the present survey the parasite was found in such small numbers that no pathogenic effects could be attributed to it.

Capillaria brevipes(Ransom,1911)--

The eggs of this parasite were found in a single animal, and no adult worms were taken. The eggs of this species measure only 24 to 26 microns wide by 49 to 53 microns long(33). The plugs at the ends of the eggs are flush with the surface of the egg.

Pathogenicity: The adult worms are found in the mucosa of the small intestine, but aside from this location its life history and pathogenicity are probably like that of Trichuris.

RHABDIASOIDIA

Strongyloides papillosus(Wedl,1856)

None of the adult worms were taken. These adults were probably missed in field post mortems because of their extremely small size and their position in the mucosa of the intestine. The eggs were found fairly regularly and could easily be identified by the coiled larvae inside the egg and also by the small size. The eggs of this parasite measure only 31 to 36 microns by 52 to 65 microns(33).

Life history: As in all Rhabdiasoids there is a free-living generation of males and females and a parasitic generation of females only. The tiny females lay eggs containing larvae. The eggs hatch and the larvae may develop into the free-living generation or may develop directly into the infective form. According to Freeborn and Stewart there is no evidence that infective larvae can penetrate actively into the host, but that infection is per orum only(24). The adult worms are found in the small intestine.

Pathogenicity: No harmful results have been observed from this species during the present survey, but then, only slight infections were noted.

CESTODA

Anoplocephalidae

Moniezia spp.(Blanchard,1891)...sheep tapeworms.

Two species of Moniezia occur in Manitoba lambs. They are not so common in older sheep.

M.expansa(Rudolphi,1810)...

The intraproglottidal glands in this species are arranged in a row at the base of each proglottis, and extend almost the full width of the proglottis. Each gland is oval and surrounds a small pit.

M.benedeni(Moniez,1879)...

The intraproglottidal gland is a solid structure at the base of each proglottis. The gland is about one third of the width of the proglottis.

Life cycle: The gravid proglottids of this tapeworm break off from the rest of the strobila and can be seen as white objects resembling cooked kernels of rice on the faecal pellets. Eggs pass out of these proglottids and on the ground are eaten by free-living mites. Stunkard showed that the eggs developed to the infective cysticercoid in the body cavity of the free-living Galumna species of mite(57). The mites are ingested by sheep when grazing. In the intestine of the sheep the cysticercoids develop to the adult tapeworms.

There is a seasonal variation in the incidence of Moniezia. Although this is a perennial parasite, relatively few Moniezia are found in sheep during the winter months.

Pathogenicity: This parasite is not highly pathogenic except when present in large numbers. Moniezia has been taken by the writer from apparently thrifty animals. Shorb artificially infected lambs with Moniezia and came to the conclusion that the animals did not show signs of unthriftiness and anemia--conditions that have often been attributed to Moniezia(52). He did find however that animals infected in this way gained weight less readily than parasite-free individuals.

<u>Cysticercus tenuicollis</u>--larval form of <u>Taenia hydatigena</u> (Pallas,1766)

<u>Description</u>: These are white, thin-walled, rounded cysts with a single scolex inside. The whole cyst is covered by an outer membrane and when this is punctured at post mortem, the scolex everts suddenly. The fluid-filled vesicle then rolls free from the organ to which it was attached. The neck of the bladder or vesicle is quite long, and the scolex is at the distal end of this neck.

<u>Life history</u>: The cysts are larval forms of <u>T. hydatigena</u>, a tapeworm of carnivores. The eggs of the tapeworms are passed with the faeces of the carnivorous hosts. The eggs contain hexacanth embryos which hatch in the intestine of the sheep and reach the liver via the blood stream(41). The embryos develop into cysts which may be found anywhere in the body cavity but are usually found on the liver. When the cysts are ingested by a suitable carnivore, such as the dog or wolf, they develop to adult tapeworms.

<u>Pathogenicity</u>: The cysts may cause the death of the host through bleeding from the liver, but normally a few cysts cause little damage(11).

Parasitic Species Not Detected In This Survey

The preceding descriptions are of parasites whose occurrence here has definitely been established. This does not preclude the possibility of other species occurring in Manitoba.

Several times during the survey, farmers described a parasite that they had removed from the bile duct of sheep. From its location, this was obviously *Thysanosoma actinioides*, the fringed tapeworm. Unfortunately this species was not encountered during the present survey, and consequently could not be included in the previous descriptions of parasites taken.

Another parasite that has possibly been missed during the present survey is *Fasciola hepatica*, the liver fluke of sheep. One farmer claimed that several of his sheep had been infected with flukes a few years previous to this survey. According to Griffiths, the potential snail vectors of Fasciola occur in Manitoba(31), and this parasite may be present in certain areas not covered in this survey. Little information regarding the snail vectors in Manitoba is available, as their distribution is quite limited.

Where single species of certain genera were taken during this survey, several species may actually occur. For instance, only one species of Trichostrongylus was taken, but several other species are widely distributed elsewhere, and may yet be found here.

Oestrus ovis, the sheep botfly or 'grub in the head' was found regularly at post mortem early in the summer, but as the season advanced, the grubs had apparently all dropped to the ground to pupate. This is not a helminth parasite, but the larval form of a large, bee-like fly, which is quite common in Manitoba. The larvae in the frontal sinuses of the sheep cause great distress to the animal.

THE CONTROL OF SHEEP PARASITES

Anthelmintic Treatment of Gastro-intestinal Nematodes

Most gastro-intestinal worms can easily be expelled by administration of drugs. A relatively new anthelmintic, phenothiazine, is particularly efficient in the expulsion of nematodes.

The writer tried the effect of phenothiazine on *Haemonchus contortus*, using two heavily parasitized lambs. Three heavily parasitized lambs had been obtained from a local packing plant as a source of *Haemonchus* eggs. One of these lambs died, and the other two were used in the phenothiazine trial.

The lambs were infected with an almost pure *Haemonchus* infection, as was shown by faecal egg-counts. This was further verified by post mortem examination of the lamb that died.

Faecal egg-counts were made for a number of days before and after the administration of phenothiazine. The worm-eggs were very concentrated in the faeces because the animals ate sparingly and thus had a small faecal output. The lambs were treated on October 10, 1944, when they each received a drench of 30 grams of phenothiazine in 4 ounces of whole milk.

The egg-counts of composite samples of faeces from the two lambs from September 28 to October 13, 1944 are given in Table VI.

TABLE VI

Faecal Egg-Counts of _Haemonchus contortus_
In Two Lambs for 13 Days Before and 3 Days After Treatment
With Phenothiazine

Date	Lamb II	Lamb III
September 28	4,400	10,600
September 29	4,000	4,000
September 30 & October 1	6,800	6,800
October 2	6,400	6,400
October 3	8,800	8,800
October 4, 5, & 6	5,800	5,800
October 7, 8, & 9	No count taken	
October 10	3,900	41,300
October 11	2,500	28,700
October 12	0	3,000
October 13	0	0

Lamb II was diarrhoeic before treatment, but this condition corrected itself one day after the administration of phenothiazine.

Lamb III refused to take any feed by October 10, and what little faeces were passed were in the form of hard pellets, and contained an abnormally high concentration of Haemonchus ova.

The first day after treatment both lambs began to eat more, and the faecal egg-count dropped considerably. On the second day after treatment no worm eggs could be found in the faeces of Lamb II, and on the following day the faeces of Lamb III were also negative.

Both lambs had regained their appetites three days after treatment. The fact that no more eggs could be found in the faeces indicates that the phenothiazine had caused the expulsion of all the adult worms.

Other investigators have obtained equally favorable results with phenothiazine in the treatment of other species of nematodes that occur here. Swales found phenothiazine highly efficient in the treatment of all the Trichostrongylid worms that occur here, and also for the hookworms and nodular worms(60). Robertson reports that phenothiazine is also effective in the removal of Chabertia ovina(48). It can be said, therefore, that phenothiazine is effective for the removal of all the common gastro-intestinal parasites that occur in Manitoba.

Some investigators have advocated the use of phenothiazine in salt and feed licks, but Gordon has found that "the amount consumed is too irregular for this to become an economic procedure"(25). Furthermore, it has been found that a single large dose of phenothiazine is more effective than an equal amount given in several doses over a period of time(45). As sheep are very tolerant to this drug, single large doses are recommended as the most economical, and the most time saving way to remove gastro-intestinal nematodes.

Lungworm Control

The investigator has not conducted any trials on the anthelmintic treatment of lungworms, but a search of the literature reveals that there are several treatments to remove this pest. Rietz recommends the use of either chloroform or "intratracheal injections of 3 to 6 cc, of an oily solution of pyrethrum"(47). Eveleth et al found that phenothiazine in glycerol or alcohol, when injected intratracheally, removed both adult and larval lungworms of sheep(20).

As none of these methods has been tried here, they can not be strongly recommended by the writer at this time. The injections of drugs by laymen is dangerous, and a competent veterinarian should be consulted before such treatment is undertaken.

Freeborn and Stewart note that lungworm disease in sheep is often cured spontaneously(24). If animals are kept in a reasonably good state of nutrition, and are kept away from low, marshy areas, they will soon free themselves of lungworm infections.

This "self-cure" of sheep from Dictyocaulus infection was noted during the present survey. A large flock was noted to have all the symptoms of lungworm infection on August 7. These animals were allowed to roam over a very large area of good brome grass pasture. The pasture area was well-drained and all the drinking water was supplied from wells. When the flock was examined again on September 14, all the sheep were in a thrifty condition and none of them was coughing. The flock owner reported that some of the aged ewes whose lungs had probably been damaged by the worms, died during the days of very hot weather. The rest the flock had recovered completely in the short space of 5 weeks without any anthelmintic medication.

The reference and observation cited above show clearly that if proper preventative measures are taken in the management of a flock, no further anthelmintic treatment will be required for Dictyocaulus in Manitoba.

Anthelmintic Treatment of Cestodes

Phenothiazine is not an efficient treatment for removal of Moniezia from the alimentary tract of sheep(60). A mixture of copper sulphate and nicotine sulphate, given as a drench in water, however, is very effective in the removal of these worms. Freeborn and Stewart call this remedy the "ideal" control for Moniezia(24).

Rietz found that tapeworm segments disappeared from the faeces when 1.5 percent solutions of copper sulphate and nicotine culphate were given at the rate of 3 ounces per adult sheep(46). Stewart and Crofton found that the copper sulphate-nicotine sulphate solution was not only more effective than phenothiazine for Moniezia, but for Nematodirus as well(56).

The copper sulphate-nicotine sulphate drench has been used by many sheep raisers in Manitoba for years, and they report satisfaction on its efficiency in tapeworm removal. During this survey, Moniezia was never found in flocks that had been treated with this drench recently.

Control of Oestris ovis

It is dangerous to attempt to destroy the grubs in the heads of sheep, but preventative methods have proved adequate in the control of this parasite. Pine tar applied to the noses of sheep will prevent the adult flies from depositing their eggs on the nostrils. An easy way to obtain an application of tar on the noses of sheep, is to bore holes in a log, and put some grain or salt in the holes. If tar is applied around these holes, the noses of feeding inevitably become smeared(17).

R. du Toit reports satisfactory treatment of severe Oestrus ovis infections by injecting 2 cc. of an equal mixture of carbon bisulphide and liquid paraffin into the frontal sinuses*. This treatment should not be attempted without advice from a competent veterinarian, as the bone over the frontal sinuses must be punctured with a trocar and canula.

* R. du Toit - The sheep nasal fly. J.S.A.V.M.A. 6:1:1935.

Overwinter Survival

From the life cycles of the worms it can be seen that the nematodes all have a free-living phase outside of the host. If this phase can be destroyed in some natural way, re-infestation of the host will be prevented. The sheep parasite problem can then be attacked in a much more positive manner.

Considerable work has been done elsewhere on this problem, and the literature on this work was studied to ascertain its application here. It has been found that certain species of worms parasitic in the sheep host do not survive over winter in regions where the climate is much milder than our own. It would appear unnecessary, then, at first thought, to carry on further experimentation on this topic here. The argument forwarded is, that with our severe winter climate the free-living stages of worms cannot survive outdoors. The problem is not as straight-forward as that, however, as other factors than temperature must be reckoned with.

Some species of worms in the infective larval stage will withstand freezing, but are killed by alternate freezing and thawing(61). In Manitoba, when the ground is once frozen, the larvae are not subjected to much freezing and thawing, but remain in the frozen condition all winter. This difference in conditions makes it imperative that the ability of the free-living stages of parasites to survive the winter here be tested. A definite answer to this question must be established for any region before recommendations for control may be made with any degree of certainty. Some work of this nature was done by the writer during the fall of 1944 and winter of 1945.

The report following covers the investigations conducted by the writer on the possibility of overwinter survival of free-living stages of *Haemonchus contortus*.

OVERWINTER SURVIVAL OF THE FREE-LIVING STAGES OF HAEMONCHUS CONTORTUS ON OUTDOOR GRASS PLOTS IN MANITOBA

Introduction

Considerable work has been done in the last few years to test the ability of some internal parasites of sheep to survive winter outdoors. Most of this work has been done at Beltsville in the United States, and some has been reported from Eastern Canada, but up to September 1944, no actual trials have been reported from Manitoba.

The results recorded in the literature indicate that *Haemonchus contortus* can not survive a normal Manitoba winter, because of the extremely low temperatures. The literature is not in complete agreement, however. The work reported from Eastern Canada is in agreement that *Haemonchus contortus* does not survive the winter, but no numerical data are given. The results from Eastern Canada indicate that alternate thawing and freezing kill the infective larvae, though they will withstand freezing over a period of time(61). A definite answer to this question is required before effective control measures can be recommended. Because this parasite is common in Manitoba sheep, and because the climatic conditions of Manitoba are vastly different from the regions where actual tests have been conducted, it was deemed advisable to test the ability of Haemonchus contortus to survive over winter under Manitoba conditions.

The life cycle of Haemonchus contortus is direct (32). The adult worms are parasitic, and are located in the fourth stomach of sheep. The females lay eggs which are passed out of the host with the faeces. The eggs hatch into larvae. There are four larval stages which develop successively. The first larval stage casts off its outer cuticle and becomes the second larval stage. The second larval stage develops into the third larval stage, but the cuticle of the second stage larvae is retained. This ensheathed larval stage is the infective stage, and migrates up moist grass blades to be eaten by sheep. In the sheep stomach, the third stage larva moults into the fourth stage larvae, which, in turn, develops into the adult stage.

It can be seen, then, that the eggs and the first three larval stages of Haemonchus contortus are free-living, while the fourth stage larvae and the adult worms are parasitic. If these free-living stages can not survive over winter, the control of this parasite is greatly facilitated. That is to say, sheep treated anthelmintically for Haemonchus before being turned out to pasture in the spring, will not become re-infected from pasture contaminated the previous season.

It was decided then to set up an experiment, starting with a known infection and by periodic recovery of eggs or larvae, to show the mortality rate of the free-living stages. The data was to be correlated with climatic conditions. If any eggs or larvae survived the winter, it was the intention to test their infectivity by drenching worm-free lambs with the larvae that developed to the infective stage.

Review of Literature

Bozevich(10) in 1930 demonstrated that larvae of *Haemonchus contortus* were still alive and active after being exposed to natural conditions (temperature not given) for 7 months, though eggs refrigerated at -2.2° C were killed in a few hours. Dickmans & Andrews(13) concluded in 1933 that experimental animals running on pastures that had been vacant since the previous fall, became infected with Haemonchus because the infection had survived the winter. These sheep had been raised under worm-free conditions in cages. Griffiths(30) in 1937 used uninfected lambs to test the survival of larvae of sheep parasites on Montreal Island in Eastern Canada. He concluded that *Haemonchus contortus* did not survive from October to May.

Baker(8) reported in 1939 that infective stages of several sheep parasites, including *Haemonchus contortus*, remained viable for at least 21 months at New York.

Swales(58) found in 1940 that the free-living stages of *Haemonchus contortus* did not survive over winter at Macdonald College, Quebec, confirming the work of Griffiths.

In 1942 Shorb(53) reported that during the summer it took less than 3½ months and probably only 2 months for infected pastures to become free of pre-parasitic stages of ovine nematodes at Beltsville, Md. He used worm-free lambs to test infectivity. Sarles(50) reported from the same station in 1943 that "pastures rested over winter are relatively if not completely free" from infective Haemonchus larvae.

In 1943 Shorb(54) further demonstrated the inability of Haemonchus to survive the winter at Beltsville, Md., but he found that the larvae survived longer if water was applied daily. In the same year, and from the same station, Kates(32) reported that Haemonchus either does not survive, or survives in very small numbers.

Dinaburg(15) in 1944 reported from Beltsville that 316 days was the longest period of exposure that infective larvae could survive if placed outdoors in the fall. When placed outdoors at other seasons, the larvae died much sooner. He reported further that a lamb grazed nine days on 2 plots containing infective larvae which had been exposed for 266 days since fall, and failed to become parasitized.

Shorb(55) in 1944, reporting on some further work at Beltsville, states that a few infective larvae of Haemonchus, exposed on grass plots in August and October, survived until the following spring, but that these surviving larvae were sluggish, vacuolated, and "probably" non-infective. Dinaburg(16) also in 1944, showed that the eggs of Haemonchus do not survive exposure for more than 20 days, temperature being the important factor.

MATERIALS AND METHODS

Two 4-foot square plots, subdivided into four 2-foot squares each, were set up as described by Shorb(55). These plots were located just north of the Science Building on heavy black earth soil. The herbage on these plots consisted chiefly of white clover and Kentucky blue grass, together with some dandelions. The grass had been kept trimmed with a lawn mower all summer, and was about 2 inches tall at the time the experiment was begun. The plots were divided by board partitions sunk into the ground to a depth of at least 4 inches.

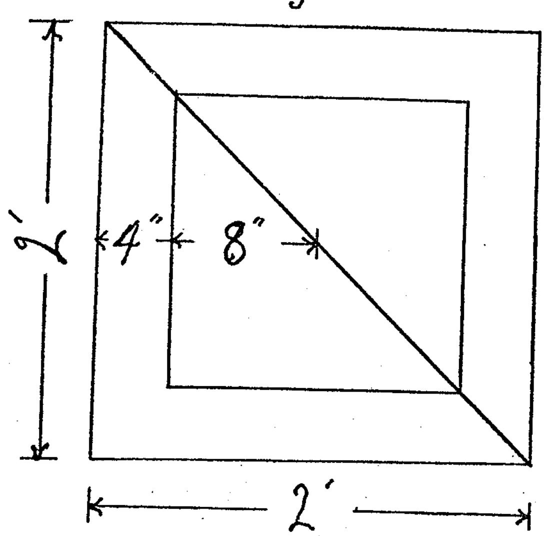
Infective material was obtained from 3 packing plant lambs, retained at the university for that purpose. These lambs maintained a faecal egg output of around 6,000 eggs per gram. The infestation was purely *Haemonchus con-*

tortus except for a few Trichuris eggs. Trichuris can easily be distinguished from Haemonchus, and as very few eggs of the former were found in the faeces, and none of the larvae were recovered from the plots, the infection was considered purely of the Haemonchus type. This was further established when one of the lambs died, and showed a very heavy Haemonchus infection at post mortem, and no other type of worm was found.

The infected lambs were kept on a cement floor and the faeces were gathered periodically. Dilution egg counts were made on the composite samples. The faeces were weighed and a portion allocated to the centre of each 2-foot square plot. Enough faeces were placed on each plot so as to inoculate it with one million Haemonchus eggs. As the lambs were in very poor condition, one dying and the other two eating sparingly, it required from October 2nd to October 5th, 1944, to obtain enough infective material to inoculate the 8 plots.

It was at first intended to take up a whole plot for examination, but this proved to be too vast. Dinaburg (15) had proved that the lateral migration of larvae in soil is negligible, and that vertical migration is limited practically to the top inch, and his method of sampling was followed. The top inch of a central triangle as shown in Figure 23 was taken up after one month's exposure. A similar sample was taken up at monthly intervals thereafter. After the first month's exposure the soil was quite frozen and an ice chisel was used to remove the soil.

Fig. 23.



Subdivision of Soil Plot

The sample in each case was taken into the laboratory, weighed, mixed by hand, quartered, and a 400 gram sample placed into the Baermann apparatus. This was allowed to stand for 24 hours, and then 60 cc of suspension were withdrawn from the bottom and examined. In several hours time, another 60 cc. sample was withdrawn and examined. Three such samples were taken for each soil sample placed in the Baermann apparatus.

In making the examination, the suspension was well mixed and a .15 cc sample was then immediately withdrawn and placed on a microscopic slide. Five such samples were examined under the microscope. The larvae on each slide were counted and the counts averaged.

Each larva was removed by means of a capillary pipette as it was counted, to avoid duplication. The average count was multiplied by 400 (60/.15) to obtain an estimate of the number of larvae in the 60 cc suspension. Counts from different 60 cc samples were totalled to get an estimate of the number of larvae obtained from the soil in the Baermann. This figure was multiplied by the number of grams soil taken from the plot, divided by 400, to get the total number of larvae from a quarter plot.

At first difficulties were encountered because of the large number of free-living, non-parasitic nematode larvae recovered from the Baermann, but after the first month these were differentiated from Haemonchus larvae by adding one part concentrated H Cl to 30 parts of suspension(51).

Repeated attempts were made to recover eggs of the parasite after one month's exposure, but this was not successful.

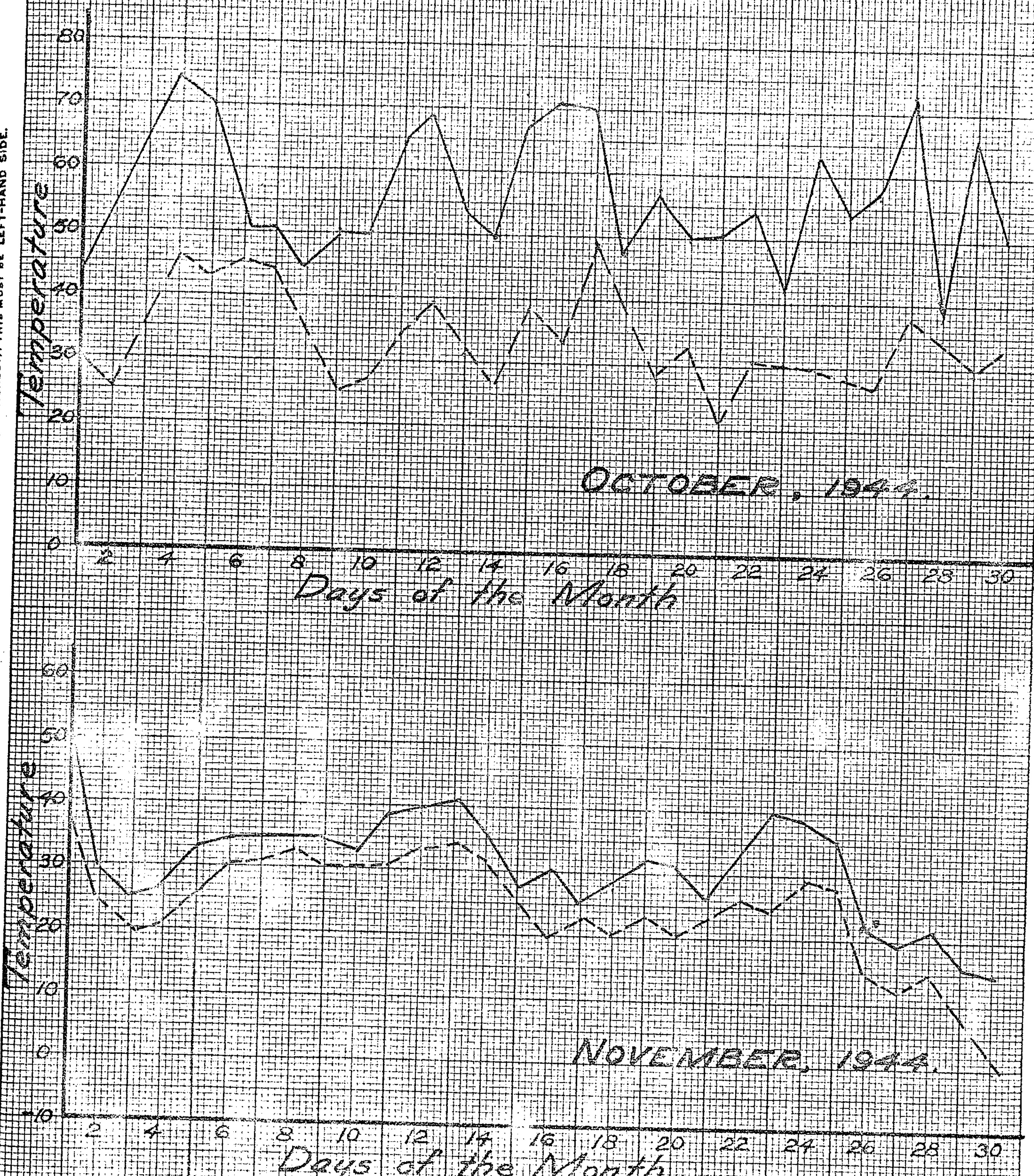
Larvae recovered were all in the 3rd stage. The kink in the tail sheath, and the well-developed buccal capsule confirmed their identification(2).

A further experiment was conducted by using tin cans of soil in place of the grass plots. These cans measured 5 inches deep by 5 inches in diameter, and the bottom was perforated to facilitate drainage. The cans were filled to within an inch of the top with sterilized soil, and sunk level to the surface in soil near the grass plots. The soil was sterilized to destroy all free-living nematodes. 100 gm. of faeces from the same lambs, and with a count of 5,800 Haemonchus eggs per gram were placed in each can on October 10th, 1944. Each can thus contained 580,000 Haemonchus eggs. The reason for using the cans was partly to eliminate non-parasitic nematode larvae, but mostly to facilitate recovery of a similar sample each month.

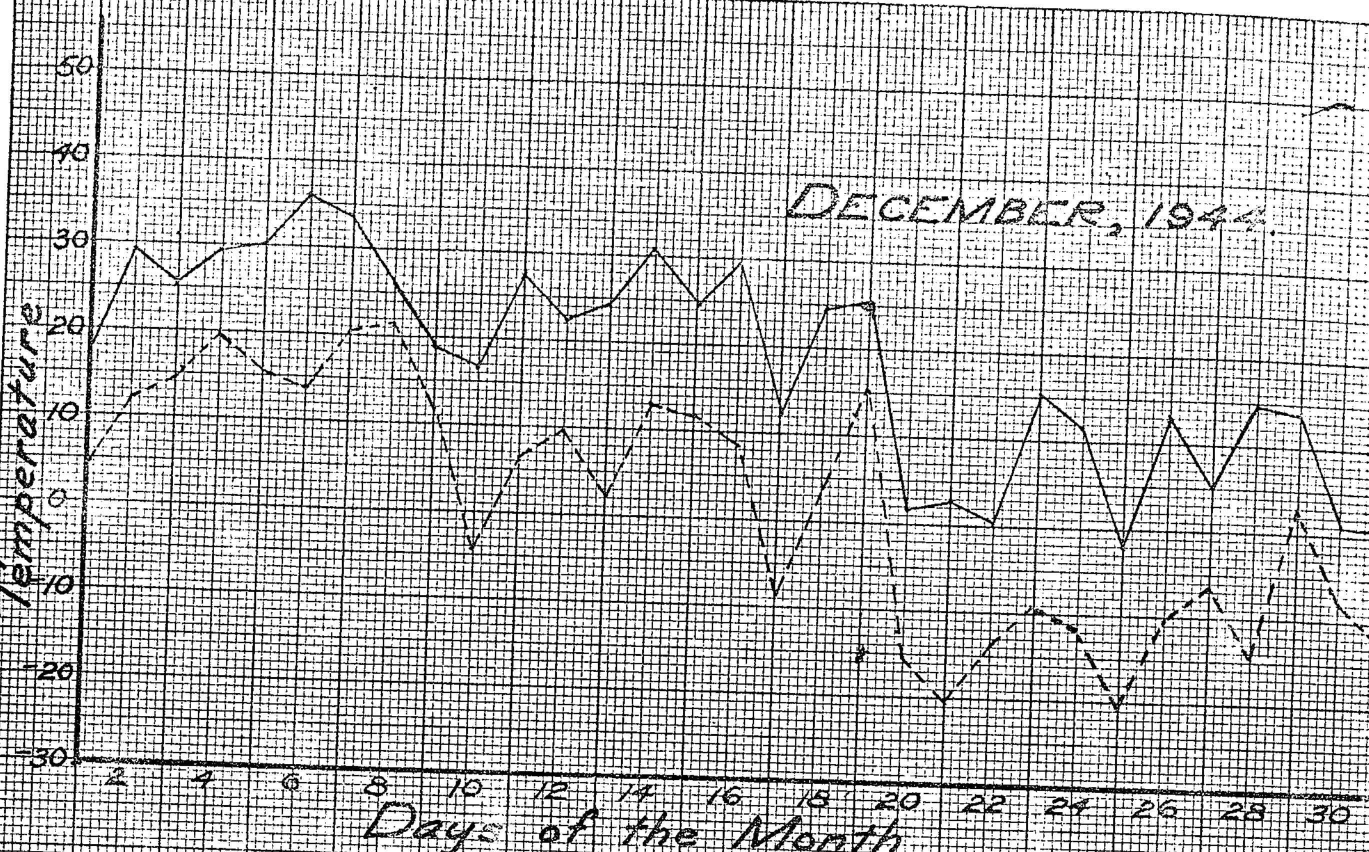
To recover the sample, a can was brought into the laboratory each month, and the top .400 gm. of soil and faeces were placed in the Baermann, and treated in the same way as samples from the grass plots.

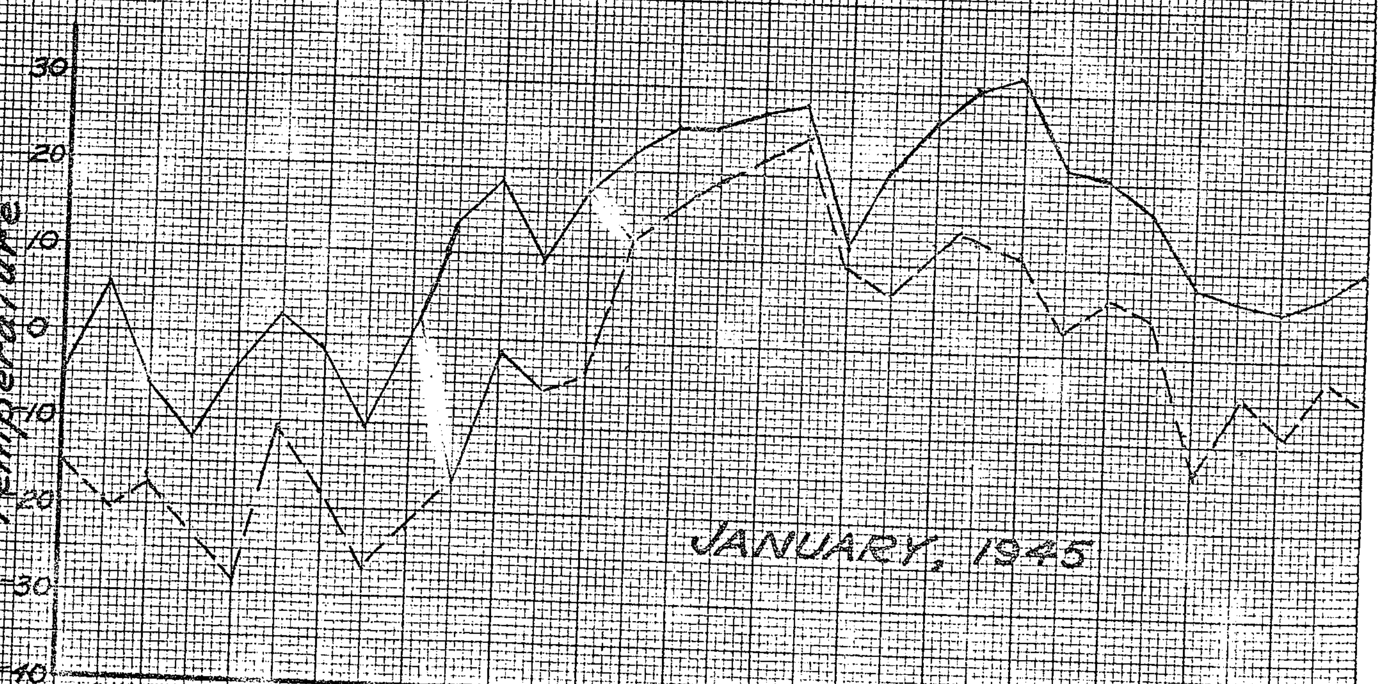
WEATHER DATA

The temperatures recorded on Graphs I and II were obtained from the Meteorological Bureau, situated approximately 10 miles from the site of the plots. It snowed on the first day of November and the cans and plots were covered with two inches or more of snow almost constantly thereafter.



Maximum and Minimum Temperatures





Maximum and Minimum Temperatures

Experimental Results

Larvae Recovered From Grass Plots

Recovery Date	Length of Exposure	Larvae Recovered	Maximum Temperature	Mean Temperature
Nov. 7th	33 days	29,800	72	19
Dec. 5th	61 "	6,880	41	-1
Jan. 6th	93 "	0	36	-31
Feb. 6th	124 "	0		
Mar. 6th	152 "	0		

Larvae Recovered From Tin Cans

Recovery Date	Length of Exposure	Larvae Recovered	Maximum Temperature	Mean Temperature
Nov. 14th	35 days	2,188	72	19
Dec. 12th	63 "	1,070	40	- 4
Jan. 13th	95 "	0	36	-31
Feb. 13th	126 "	0		
Mar. 10th	151 "	0		

DISCUSSION

The fact that no control culture of faeces was kept in the laboratory to test the hatchability of the eggs, makes it impossible to give ratios of larvae recovered to larvae placed on grass plots. The number of larvae recovered from the grass plots after the first month of exposure may be high, due to the presence of non-parasitic nematode larvae of the soil. This possibility was later eliminated by the method of Shorb, as previously mentioned.

Swales has pointed out the importance of soil temperatures, but the records were not kept here. However, with an air temperature of -30° F, the soil was frozen solid to a much greater depth than the larvae of Haemonchus are known to migrate. This is true despite considerable snow coverage. The chief use of the temperature data is to show that during the experimental period the temperature was normal for Manitoba.

The time interval between recoveries of larvae was too great to give a picture of the mortality rate of the larvae, except that it indicates that the initial death rate is high.

The method of sampling soil in the case of the grass plots is not altogether satisfactory, because the whole sample cannot be examined and it does not show what proportion of the original infective material is included in the sample. There are objections also to the Baermann method of recovery, as pointed out by Dinaburg(14). These various inaccuracies show that the larvae recovered were the minimum for the particular sample. The significant facts are:

1. That at first considerable numbers of larvae were recovered by the methods used, and that these numbers were reduced as the length of exposure increased.

2. That no larvae were recovered after December.

Dinaburg(16) has shown that temperature is a more important factor than humidity for the survival of <u>Haemonchus contortus</u>. The recovery interval in these tests was too great, however, to indicate a critical temperature.

It may be that the larvae were killed by the continuous low temperatures during December, or by the sudden drop to -32° F on January 5th. In any case, the conditions are quite normal for this area, and it is safe to say that the free-living stages of Haemonchus contortus do not winter over on Manitoba pastures.

The repeated failure to recover eggs of Haemonchus contortus after one month's exposure outdoors, gives support to the work of Dinaburg(16), showing that these eggs do not survive outdoors for more than about 20 days. It appears that they either hatch or disintegrate within a month's time, in the fall at least.

The data from the grass plots and tin cans agree fairly well. The exceptionally high larval count from the first grass plot has already been explained as due to the presence of non-parasitic nematode species. Aside from this, however, the counts on grass plots appear slightly higher than the ones from tin cans. For instance, the 6,880 larvae recovered from a grass plot December 5th represents .688% of the original inoculum. This recovery was only from a quarter plot, and the percentage might equally well be taken as twice .688%, allowing that larvae probably would not migrate to the outer quarter plots. On the other hand, the comparable recovery from the tin can was 1,070 larvae or .184% of the original inoculum. The lower recovery from cans probably is due to the absence of grass blades, as many larvae are normally recovered from grass(15).

CONCLUSIONS

The free-living stages of the sheep stomach worm, Haemonchus contortus, do not survive outdoors over a normal Manitoba winter.

Sheep rendered free from Haemonchus infection before being turned out to pasture in the spring, will continue to be free from this infection, unless a new source of infection is brought in.

DISCUSSION

Although only 28 percent of all the sheep examined showed evidence of parasitism, there are areas where the incidence is as high as 60 percent. In these same districts every flock examined showed some evidence of parasitism. These flocks were chosen at random, and the animals selected included both lambs and ewes. This means that in certain areas every sheep is parasitized to some extent, or at least that every sheep is exposed to parasitic infection early in life--the most susceptible age for sheep. Every flock in some districts exhibited evidence of some parasitic infection.

The most prevalent helminth parasites in Manitoba sheep are the Trichostrongylid worms. Chabertia and Bonostomum are also very common. Moniezia is very common in lambs, but farmers are more apt to recognize its presence by the white segments that are passed in the faeces, and to take corrective measures.

Dictyocaulus, hitherto unreported from Manitoba sheep is very common. Although not nearly as prevalent as the previously-mentioned worms, it does occur wherever sheep are allowed access to low, marshy ground and sloughs.

Oesophagostomum is not very prevalent, but it takes such a heavy toll in other regions, that every precaution should be taken to prevent the spread of this dreaded parasite.

The percentage of sheep infected with any one genus is not high, but there are many related forms, all of which even in pure infections produce similar harmful effects. Even though the number of genera per sheep is low as compared to certain other regions, infections of this kind can terminate fatally if they are severe. Infections of single species, even in a mild form result in the uneconomic utilization of feed.

The Trichostrongylid worms are very general in their distribution in the province. This is also true of Chabertia and Bunostomum. Chabertia, for some unknown reason, was not found in the western part of the Interlake area. This parasite, because of its position in the colon, may have been overlooked by the writer during the survey, as all post mortems were done hurriedly. There does not seem to be any other logical explanation why Chabertia should occur in every other part of the province and not in this area, where all other forms are so common.

The parasitological centre for all the helminths of sheep in Manitoba appears to be east of the Red River and in the Interlake country. Larger flocks, poorer management, soil type, climate and frequent feed shortage may all be causative factors.

The western part of the province, which is the true prairie region, is practically free of sheep parasites. In the Pilot Mound and Boissevain areas there was practically no evidence of parasitic infections in any of the flocks examined. The sheep population is small in these areas, and the small flocks have an abundance of pasture to roam over.

Even in areas where sheep parasites are common, they can be kept in check by anthelmintic medication. This demands an outlay of cash by the farmer, and is costly if not carried out in a systematic manner. The first step in controlling parasitic infections is to take proper preventative measures. Sheep raisers should not try to raise more animals than their land will support adequately, because otherwise a good nutritional state cannot be maintained and consequently the resistance to infection is lowered. If this prerequisite is fulfilled, the whole flock will be thrifty and much more resistant to infection, than is often the case now. Sheep in a poor nutritional state are particularly susceptible to parasitic infections, and if areas are overpopulated, heavy worm-burdens are acquired in a short period of time.

It has been shown that Haemonchus does not survive overwinter in Manitoba, otherwise than in the host. Most of the other forms are very similar to Haemonchus in their life cycles and it may be assumed that the majority of these, at least do not survive the winter outdoors either.

It has also been shown that Haemonchus and other parasites can be eliminated easily from the host by the administration of phenothiazine.

The practical way to eliminate losses from parasitism is to keep animals in a thrifty condition and away from sloughs and marshes. In areas where losses from parasites are common, all sheep should be treated with phenothiazine when they come off pastures in the fall. By eliminating worm-burdens early, the expense of extra feed for unthrifty sheep will be avoided, the free-living stages of the parasites will be destroyed outdoors over winter, and parasite-free sheep can then be turned on to clean pastures in the spring.

Sometimes it will be necessary to treat for worms twice in a year, because 100 percent efficiency in worm removal can not be guaranteed, and should not be expected. If some worms are carried over inside the host, a pasture can become re-infected in a short time, if conditions for the development of the free-living stages of the parasites are favorable.

Although elimination of losses incident to parasitism can easily be achieved, the approved methods are not well known to flock masters. Many owners are completely ignorant of the existence of parasites and their relation to sheep losses. Hence the conclusion seems inescapable that a remedial programme rests on an extension educational campaign.

SUMMARY

About 28 percent of all the sheep in Manitoba are parasitized to some extent, as shown by faecal egg-counts. There is evidence of parasitic infection in 76 percent of all the flocks examined in Manitoba. In some areas parasitic infections are present in every flock, and 60 percent of all the sheep in such areas are parasitized. In other areas sheep are practically free from parasitic infections.

Fifteen different genera of parasites occur in Manitoba sheep, and of these 13 are nematodes and 2 are cestodes. Of the nematodes, 6 genera are Trichostrongylids. These are general in distribution over most of the province, as are also Chabertia and Bunostomum.

There is evidence that Oesophagostomum occurs only in the south-eastern part of Manitoba.

Dictyocaulus is the only lungworm found in Manitoba sheep, and it is quite common.

Other nematodes sometimes found in Manitoba sheep are Trichuris, Capillaria and Strongyloides.

Two species of Moniezia, _expansa_ and _benedeni_, occur in Manitoba. The other cestode found here is the larval form of _T_. _hydatigena_, called _Cysticercus_ _tenuicollis_.

The descriptions, life cycles and pathogenicity of the parasites are given, with photographic illustrations of distinguishing features.

The free-living stages of _H_. _contortus_, a common

Trichostrongylid form of parasite, can not survive the winter outdoors in Manitoba. Elimination of the adult can be accomplished easily by the use of phenothiazine. The most effective time for treatment being the off-pasture season.

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